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ABSTRACT

The theme of this symposium was "Opening the Doors to the Future: Education in the Classroom and Beyond." Presentations, both oral and poster, are devoted to both K-12 and university educational issues in meteorological and oceanographic education. Oral presentations include: (1) "The Bachelor's Degree in Atmospheric Science-Revision of the 1987 AMS Statement" (Phillip Smith, S. Businger, E. Pani, and J. Zebransky); (2) "Meteorology's Educational Dilemma" (Paul Croft and M. Binkley); (3) "Involvement of Undergraduate Meteorology Students in Faculty Research Projects" (Gregory Byrd, R. Weinback, R. Ballentine, A. Stamm, and E. Chermack); (4) "Creating and Maintaining Enthusiasm for the Undergraduate Major" (Dayton Vincent and P. Smith); (5) "Weather Education at the Introductory College Level" (Robert Weinback and I. Greer); (6) "Weather and Life: A Cognitive Apprenticeship in Personalized Multidisciplinary Problem Solving" (Paul Croft and M. Tessmer); (7) "New Meteorology Program at the U.S. Air Force Academy Integrates Comet Multimedia and Computer Weather Lab into Undergraduate Curriculum" (Thomas Koehler, K. Blackwell, D. Knipp, B. Heckman); (8) "Integration of Interactive Multimedia into the Meteorology Curriculum at the United States Air Force Academy" (Delores Knipp and B. Heckman); (9) "A Survey of the Use of COMET's(R) Forecaster's Multimedia Library in the Academic Community" (Brian Heckman); (10) "Symbolic Manipulators in the Classroom: Using Student Research Topics in Oceanography and Meteorology to Enhance Teaching/Learning of Advanced Mathematics" (Reza Malek-Madani, D. Smith, and C. Gunderson); (11) "Classroom Applications of Interactive Meteorological Visualization" (Michael Biggerstaff and J. Nielsen-Gammon). The poster presentations include topics of interest for both K-12 and university educators. Two joint sessions focused on K-12 educational programs and new technologies for the classroom. The joint session with the 11th Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology included demonstrations of hardware and software systems designed to enhance meteorological and oceanographic education. Contains an author index. (JRH)

FOURTH SYMPOSIUM ON EDUCATION

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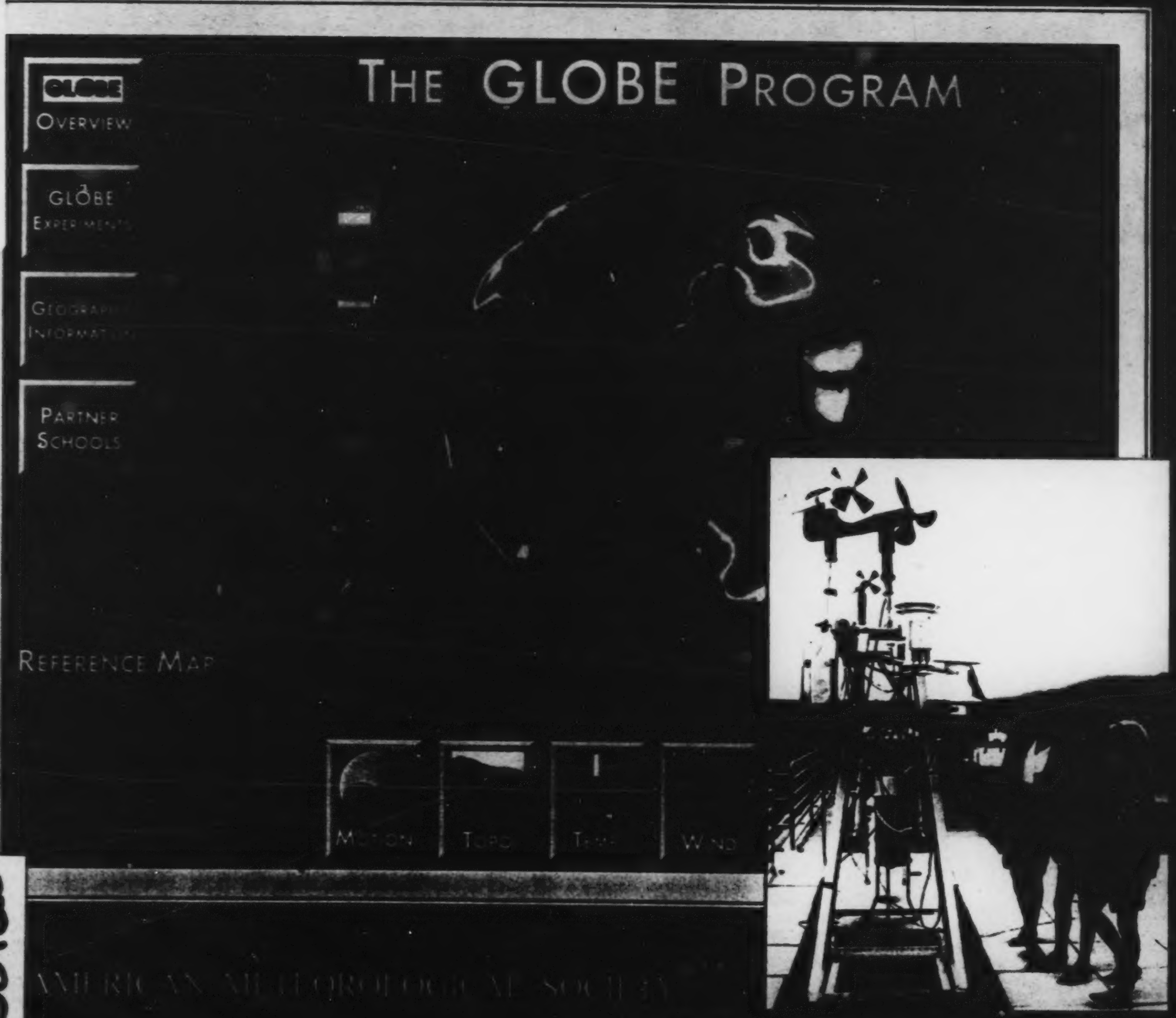
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FOURTH CONFERENCE ON EDUCATION

January 15-20, 1995 Dallas, Texas

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Front Cover: Global Learning and Observations to Benefit the Environment (GLOBE) is a new international environmental education program established earlier this year by Vice President Al Gore. Its objectives are to increase understanding of environmental issues among the children of the world and to collect observations important to environmental scientists.

Many schools participating in the GLOBE program will use the Multimedia GLOBE School Display System shown on the cover for classroom GLOBE activities. This system is being developed by NOAA's Forecast Systems Laboratory in Boulder, Colorado. In addition to schools within the United States, over 100 other countries have formally indicated a desire to participate in the GLOBE program.

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FOREWORD

In 1992, the Board on School and Popular Meteorological and Oceanographic Education (BSPMOE) and the Board on Meteorological and Oceanographic Education in Universities (BMOEU) jointly sponsored the First AMS Symposium on Education as part of the AMS Annual Meeting. Since that time, the amount of interest in educational issues has increased dramatically throughout the atmospheric and oceanic communities. Precollege educational activity has received a tremendous stimulus with the emergence of Project ATMOSPHERE and several other K-12 educational programs across the country. Further, there has been renewed interest in university educational issues at the undergraduate and graduate levels, as programs attempt to cope with increasing technology and an expanding knowledge-base in the atmospheric and oceanic sciences. The primary purpose of the Symposium on Education is to acquaint the general membership of the Society with new educational initiatives within AMS and its constituent membership.

The Fourth AMS Symposium on Education is held in conjunction with the 75th AMS Annual Meeting. The theme of this Symposium is "Opening the Doors to the Future: Education in the Classroom and Beyond." Presentations, both oral and poster, are devoted to both K-12 and university educational issues. This year the K-12 Educational Program includes a joint session with the 24th Conference on Broadcast Meteorology. There is also a poster session which has attracted a record number of presenters and includes topics of interest for both K-12 and university educators. University papers focus on introductory meteorology courses, undergraduate research activities, new requirements for the bachelor's degree in atmospheric science, and emerging technologies for the classroom. There is a joint session with the 11th Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology, with demonstrations of hardware and software systems designed to enhance meteorological and oceanographic education.

The papers and posters presented at this year's conference clearly demonstrate how much our educational involvement has increased in recent years. Further, the evolving programs and emerging technologies can open doors of opportunity for the future of atmospheric and oceanic science education.

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Symposium Cochairperson

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TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

iii **FOREWORD**

xi **AUTHOR INDEX**

SESSION 1: UNIVERSITY EDUCATIONAL PROGRAMS

1 1.1 THE BACHELOR'S DEGREE IN ATMOSPHERIC SCIENCE - REVISION OF THE 1987 AMS STATEMENT. Phillip J. Smith, Purdue Univ., W. Lafayette, IN; and S. Businger, E. Pani, and J. Zebransky

3 1.2 METEOROLOGY'S EDUCATIONAL DILEMMA. Paul J. Croft, Univ. of South Alabama, Mobile, AL; and M. S. Binkley

9 1.3 INVOLVEMENT OF UNDERGRADUATE METEOROLOGY STUDENTS IN FACULTY RESEARCH PROJECTS. Gregory P. Byrd, State Univ. of New York (SUNY), Brockport, NY; and R. S. Weinbeck, R. J. Ballentine, A. J. Stamm, and E. E. Chermack

11 1.4 CREATING AND MAINTAINING ENTHUSIASM FOR THE UNDERGRADUATE MAJOR. Dayton G. Vincent, Purdue Univ., W. Lafayette, IN; and P. J. Smith

15 1.5 WEATHER EDUCATION AT THE INTRODUCTORY COLLEGE LEVEL. Robert S. Weinbeck, SUNY, Brockport, NY; and I. W. Geer

19 1.6 WEATHER AND LIFE: A COGNITIVE APPRENTICESHIP IN PERSONALIZED MULTI-DISCIPLINARY PROBLEM SOLVING. Paul J. Croft, Univ. of South Alabama, Mobile, AL; and M. A. Tessmer

23 1.7 NEW METEOROLOGY PROGRAM AT THE U.S. AIR FORCE ACADEMY INTEGRATES COMET MULTIMEDIA AND COMPUTER WEATHER LAB INTO UNDERGRADUATE CURRICULUM. Thomas L. Koehler, U.S. Air Force Academy, Colorado Springs, CO; and K. G. Blackwell, D. J. Knipp, and B. E. Heckman

25 1.8 INTEGRATION OF INTERACTIVE MULTIMEDIA INTO THE METEOROLOGY CURRICULUM AT THE UNITED STATES AIR FORCE ACADEMY. Delores J. Knipp, U.S. Air Force Academy, Colorado Springs, CO; and B. E. Heckman

29 1.9 A SURVEY OF THE USE OF COMET'S* *FORECASTER'S MULTIMEDIA LIBRARY* IN THE ACADEMIC COMMUNITY. Brian E. Heckman, Univ. Corporation for Atmospheric Research (UCAR), Boulder, CO

34 1.10 SYMBOLIC MANIPULATORS IN THE CLASSROOM: USING STUDENT RESEARCH TOPICS IN OCEANOGRAPHY AND METEOROLOGY TO ENHANCE TEACHING/LEARNING OF ADVANCED MATHEMATICS. Reza Malek-Madani, U.S. Naval Academy, Annapolis, MD; and D. R. Smith and C. R. Gunderson

37 1.11 CLASSROOM APPLICATIONS OF INTERACTIVE METEOROLOGICAL VISUALIZATION. Michael I. Biggerstaff, Texas A&M Univ., College Station, TX; and J. W. Nielsen-Gammon

POSTER SESSION P1: K-12 AND UNIVERSITY EDUCATION PROGRAMS

41 P1.1 USING *MATHEMATICA* TO ENHANCE LEARNING OF ATMOSPHERIC PROCESSES: ENTRAINMENT INTO CUMULUS CLOUDS. Julie A. Preyer, U.S. Naval Academy, Annapolis, MD; and D. R. Smith and R. Malek-Madani

---

* Manuscript not available

TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

44 P1.2 USING *MATHEMATICA* TO ENHANCE LEARNING OF OCEANOGRAPHIC PROCESSES: WIND-DRIVEN CIRCULATION. Brent M. Strong, U.S. Naval Academy, Annapolis, MD; and C. R. Gunderson and R. Malek-Madani

47 P1.3 A MULTIDISCIPLINARY APPROACH FOR TEACHING ABOUT ENSO: APPLYING THE FIVE THEMES OF GEOGRAPHY TO TOPICS IN METEOROLOGY AND OCEANOGRAPHY. Peggy L. Killam Smith, St. Mary's High School, Annapolis, MD; and D. R. Smith

50 P1.4 USING *MATHEMATICA* TO ENHANCE LEARNING OF OCEANOGRAPHIC PROCESSES: BREAKING OF WAVES AND BURGERS' EQUATION. Camille A. Garrett, U.S. Naval Academy, Annapolis, MD; and R. Malek-Madani

54 P1.5 WEATHER RELATIVE TO A RELATIVE. Lawrence E. Greenleaf, Atmospheric Education Resource Agent (AERA) Project ATMOSPHERE, Belfast Area High School, Belfast, ME

56 P1.6 AIR-SEA INTERFACE EDUCATION. Lawrence E. Greenleaf, AERA Project ATMOSPHERE, Belfast Area High School, Belfast, ME

58 P1.7 SCHOOLS OF THE PACIFIC RAINFALL CLIMATE EXPERIMENT: BRINGING GLOBAL ISSUES TO THE LOCAL CLASSROOM. Susan Postawko, Univ. of Oklahoma, Norman, OK; and M. Morrissey and B. Gibson

59 P1.8 THE ARM EDUCATIONAL OUTREACH MANUAL FOR OKLAHOMA TEACHERS. Stephen J. Stadler, Oklahoma State Univ., Stillwater, OK; and T. Mills, R. A. McPherson, and K. Crawford

63 P1.9 INTRODUCING THE MODERNIZED NATIONAL WEATHER SERVICE TO PRIMARY AND SECONDARY SCHOOLS. Michael A. Mach, NOAA/National Weather Service Forecast Office (NWSFO), Ft. Worth, TX; and J. J. Johnson

68 P1.10 THE EXCITEMENT OF METEOROLOGY! AN INTERACTIVE STUDY IN THE GEOSCIENCES. Paul J. Croft, Univ. of South Alabama, Mobile, AL; and A. Williams, Jr.

70 P1.11 ON-LINE CLIMATE RESOURCES FOR THE CLASSROOM. E. Hope Poteat, Southeast Regional Climate Ctr. (SRCC), Columbia, SC

72 P1.12 SHARING WEATHER WITH CHILDREN: A GUIDE FOR METEOROLOGIST, ENGINEERS, AND OTHER SCIENTIST. Steve Carlson, AERA Project ATMOSPHERE, Blaine County Schools, Hailey, ID

78 P1.13 WEATHER: AN INTERDISCIPLINARY APPROACH. Rene T. Carson, Little Rock School District, Little Rock, AR

80 P1.14 ILLINOIS CLIMATE NETWORK EDUCATIONAL OUTREACH ACTIVITIES. Beth C. Reinke, Illinois State Water Survey (ISWS), Champaign, IL; and R. A. Peppler

82 P1.15 THE FLORIDA STATEWIDE WEATHER NETWORK. Paul Ruscher, Florida State Univ. (FSU), Tallahassee, FL; and K. Kloesel, W. Jordan, S. Graham, and L. Mazarowski

86 P1.16 TECHNOLOGY AND RESEARCH PARTNERSHIP: THE NEXT STEP IN METEOROLOGICAL INTERNSHIP PROGRAMS FOR HIGH SCHOOL STUDENTS. William R. Krayer, Gaithersburg High School, Gaithersburg, MD

* Manuscript not available

TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

90 P1.17 ESTABLISHING PARTNERSHIPS BETWEEN BUSINESSES AND SCHOOLS. Hector Ibarra, West Branch Middle School, West Branch, IA

93 P1.18 PROJECT ATMOSPHERE GIVES TEACHERS A NEW LOOK AT THE WATER CYCLE. Jerri J. Johnson, AERA Project ATMOSPHERE, Barton Elementary School, Irving, TX

94 P1.19 PROJECT WEATHERWATCH: A COOPERATIVE METEOROLOGICAL EFFORT BETWEEN PROJECT ATMOSPHERE AND THE GREATER NEWARK CONSERVANCY. Richard L. Lees, Lyndhurst High School, Lyndhurst, NJ

96 P1.20 LIGHTNING HAZARD EDUCATION. Ronald L. Holle, NOAA/National Severe Storms Lab. (NSSL), Norman, OK; and R. E. Lopez, K. W. Howard, R. J. Vavrek, and J. Allsopp

P1.21 PAPER WITHDRAWN

152 P1.21A FORECASTING THE FUTURE: TEACHING ABOUT GLOBAL CLIMATE CHANGE. Hung Nguyen, Scripps Inst. of Oceanography (SIO), Univ. of California, San Diego; and S. Franks and S. Birch

100 P1.22 HOW'S THE WEATHER UP THERE? ...DOWN THERE?...AND OVER THERE? Kathleen A. Murphy, St. Anthony's School, High Ridge, MO

103 P1.23 A POLAR EXPRESS - NEW YORK TO TEXAS. Rose Marie Camarda, Syracuse City Schools, Syracuse, NY

105 P1.24 OKLAHOMA SCHOOLS VIEW THE 10 MAY 1994 ECLIPSE. Renee A. McPherson, Univ. of Oklahoma, Norman, OK

111 P1.25 A GUIDE TO TORNADO PREPAREDNESS PLANNING IN SCHOOLS. Michael A. Mach, NOAA/NWSFO, Ft. Worth, TX

116 P1.26 ATMOSPHERIC CLASSROOMS: THE FUTURE IS NOW. Faye McCollum, AERA Project ATMOSPHERE, Muscogee County School District, Columbus, GA

119 P1.27 PREPARING FOR THE FUTURE OF ATMOSPHERIC SCIENCES BY LEARNING ABOUT THE PAST. Natalija Janc, Millersville, MD

121 P1.28 A NEW LOOK TO THE SKY. Jonet Anderson, EarthWatch Communications, Minnetonka, MN; and J. J. Johnson

123 P1.29 FROM THE GROUND TO THE SKY. Matthew Gilmore, Texas A&M Univ., College Station, TX; and J. J. Johnson

125 P1.30 USING SCIENTIFIC THEORY AS METAPHOR TO ENHANCE EQUITY IN URBAN PRIMARY SCHOOLS. John P. Byrne, Jamaica Plain Community Ctrs. at the Agassiz School, Boston, MA

* P1.31 META-ANALYSIS OF MINORITIES ENTERING SCIENTIFIC FIELDS. Elvia Solis, Illinois State Univ., Normal, IL

P1.32 *This paper has been transferred to Joint Session J1, paper # J1.10A*

153 P1.32A AN INTERDISCIPLINARY CONNECTION FOR SCIENCE, MATH, ENGLISH, SOCIAL STUDIES AND HEALTH IMPLEMENTED BY THE USE OF THE INQUIRY METHOD. Judy A. Lee, William R. Blocker Middle School, Texas City, TX; and A. Maier

---

* Manuscript not available

TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

* P1.33 TEXTBOOKS FOR TEACHING METEOROLOGY AT THE ELEMENTARY AND MIDDLE SCHOOL LEVELS. Jonathan D. W. Kahl, Univ. of Wisconsin, Milwaukee, WI

129 P1.34 UNIVERSITY OF WYOMING INITIATIVE FOR RESEARCH AVIATION. A. R. Rodi, Univ. of Wyoming, Laramie, WY; and J. D. Marwitz

131 P1.35 AN AVIATION WEATHER MINOR AT EMBRY-RIDDLE AERONAUTICAL UNIVERSITY. Richard Bagby, Embry-Riddle Aeronautical Univ., Daytona Beach, FL

133 P1.36 STUDENT PERCEPTIONS OF CLIMATIC CHANGE. Kent M. McGregor, Univ. of North Texas, Denton, TX; and M. D. Schwartz

139 P1.37 YOU HAVE THE DATA. NOW WHAT? Elliot Abrams, Accu-Weather, Inc., State College, PA; and J. Levin

141 P1.38 HIGH SCHOOL STUDENT BASED STUDIES EMPHASIZING THE IMPORTANCE OF METEOROLOGY IN UNDERSTANDING THE GLETSCHERVORFELD ENVIRONMENT: LOCATION — BODALSBREEN, JOSTEDALEN, NORWAY. Jennifer Lykens, State College Area High School, State College, PA; and M. A. MacDonald, P. R. McCormick, S. B. Bremner, and R. G. Meldrum

144 P1.39 MICROMETEOROLOGICAL STUDIES IN THE BODALEN GLACIAL VALLEY, NORWAY INTERPRETATION OF THE ENERGY BUDGE OBSERVATIONS. Eric Y. Lee, State College Area High School, State College, PA; and M. A. MacDonald, E. S. Thomson, D. J. Higgins, and C. A. Williams

148 P1.40 STUDIES OF WINDS IN THE BODALSBREEN VALLEY IN NORWAY. Jennifer Lykens, State College Area High School, State College, PA; and E. Y. Lee, P. R. McCormick, E. S. Thomson, D. J. Higgins, and C. A. Williams

150 P1.41 LOOKING AT EARTH FROM SPACE. Colleen J. Steele, W.T. Chen & Co., Arlington, VA

* * * PAPERS IN THE FOLLOWING JOINT SECTIONS HAVE BEEN EDGED IN GREY * * *

JOINT SESSION J1: K-12 EDUCATIONAL PROGRAMS (Joint with 24th Conference on Broadcast Meteorology)

(J1) 1 J1.1 MAP READING AND INTERPRETATION SKILLS DISPLAYED BY HIGH SCHOOL FRESHMEN. Paul J. Mroz, Spencerport Central Schools and WOKR-TV, Rochester, NY

(J1) 5 J1.2 EDUCATIONAL PARTNERSHIPS LEADING TO THE PROMOTION OF STUDENT CENTERED METEOROLOGICAL FIELD STUDIES IN A GLETSCHERVORFELD ENVIRONMENT. JOSTEDALEN, NORWAY. George G. Meldrum, James Gillespie's High School, Edinburgh, UK; and T. C. Arnold

(J1) 10 J1.3 PROJECT ATMOSPHERE: AMS PRECOLLEGE EDUCATIONAL INITIATIVE - AN OVERVIEW OF PROGRESS. Ira W. Geer, American Meteorological Society (AMS), Washington, DC; and D. R. Smith, R. S. Weinbeck, and J. T. Snow

(J1) 13 J1.4 THE MAURY PROJECT: A TEACHER ENHANCEMENT PROGRAM IN PHYSICAL OCEANOGRAPHY. David R. Smith, U.S. Naval Academy, Annapolis, MD; and P. L. Guth, M. E. C. Vieira, D. W. Jones, J. F. H. Atangan, D. S. Dillner, C. A. Martinek, A. E. Strong, E. J. Miller, R. D. Middleton, G. A. Eisman, D. E. McManus, and I. W. Geer

---

* Manuscript not available

TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

(J1) 17 J1.5 THE WEATHERWATCH LEADERSHIP NETWORK. Steven J. Richards, City College of New York, New York, NY

* J1.6 FORMING PARTNERSHIPS: PRECOLLEGE TEACHERS, ACADEMIA, INDUSTRY, GOVERNMENT, AND THE PRIVATE SECTOR. Sharon H. Walker, Gulf Coast Research Lab., Ocean Springs, MS

* J1.7 THE EVOLVING "NATIONAL SCIENCE EDUCATION STANDARDS": AN UPDATE. John T. Snow, Univ. of Oklahoma, Norman, OK

(J1) 20 J1.8 HOW DID YOU BECOME INTERESTED IN ENVIRONMENTAL SCIENCE? Anne-Marie Henry, Environment Canada, Winnepeg, Manitoba, Canada

J1.9 PAPER WITHDRAWN

* J1.9A BLUE SKIES 2.0: INTERACTIVE GRAPHICS OVER THE INTERNET. Alan Steremberg, Univ. of Michigan, Ann Arbor, MI; and J. Ferguson and P. J. Samson

J1.10 PAPER WITHDRAWN

* J1.10A A REPORT ON GENDER DISCRIMINATION IN THE 1990s. M. J. Ceritelli, Immaculate Conception School, Worthington, OH *(transferred from paper # P1.32)*

(J1) 22 J1.11 4-WINDS, A TELEVISION EDUCATION PARTNERSHIP. Robert T. Ryan, WRC-TV, Washington, DC

(J1) 25 J1.12 THE COOPERATIVE EFFORTS OF EDUCATION RESOURCES ENHANCES THE PRODUCT. Raymond L. Boylan, WSOC-TV, Charlotte, NC; and H. P. Warthan

JOINT SESSION J6: NEW TECHNOLOGIES FOR THE CLASSROOM (Joint with 11th Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology)

(J6) 1 J6.1 EXPLORING THE USE OF WEATHER SATELLITES IN THE K-12 CLASSROOM. Kevin Kloesel, FSU, Tallahassee, FL; and P. Ruscher, S. Graham, F. Lans, and S. Hutchins

(J6) 3 J6.2 BRINGING McIDAS TECHNOLOGY INTO THE HIGHSCHOOL CLASSROOM. Thomas Achtor, Univ. of Wisconsin, Madison, WI; and W. L. Smith, L. Buescher, and R. Graewin

(J6) 5 J6.3 BUILDING PARTNERSHIPS THROUGH EARTHLAB. Edward J. Hopkins, Ross Computational Resources, Madison, WI

(J6) 9 J6.4 A COLLABORATIVE INTERDISCIPLINARY UNIT ON WEATHER FOR ELEMENTARY EDUCATORS ON THE INTERNET. Dee A. Chapman, Univ. of Illinois, Urbana, IL; and D. E. Novak and W. L. Chapman

(J6) 13 J6.5 CoViS: A NATIONAL SCIENCE EDUCATION COLLABORATORY. Mohan K. Ramamurthy, Univ. of Illinois, Urbana, IL; and R. B. Wilhelmson, R. D. Pea, L. M. Gomez, and D. C. Edelson

(J6) 19 J6.6 THE DAILY PLANET™: AN INTERNET-BASED INFORMATION SERVER FOR THE ATMOSPHERIC SCIENCES COMMUNITY AND THE PUBLIC. Robert B. Wilhelmson, Univ. of Illinois, Urbana, IL; and M. K. Ramamurthy, D. Wojtowicz, J. Kemp, S. Hall, and M. Sridhar

(J6) 23 J6.7 COMET®: A PROGRAM UPDATE AND LOOK TO THE FUTURE. Timothy C. Spangler, UCAR, Boulder, CO; and V. C. Johnson

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TABLE OF CONTENTS

FOURTH SYMPOSIUM ON EDUCATION

PAGE

(J6) 29 J6.8 AN UPDATE ON NCDC'S CD-ROM PRODUCTS AND ON-LINE SERVICES AVAILABLE FOR EDUCATORS. Thomas F. Ross, NOAA/National Climatic Data Ctr. (NCDC), Asheville, NC

(J6) 34 J6.9 THE USE OF HYPERTEXT CLIMATOLOGIES TO TRAIN WEATHER FORECASTERS. Scott A. Straw, U.S. Air Force Environmental Technical Applications Ctr. (USAFETAC), Scott AFB, IL; and K. R. Walters, Sr.

(J6) 37 J6.10 A NATIONWIDE NETWORK OF AUTOMATED WEATHER STATIONS: USING REAL-TIME WEATHER DATA AS A HANDS-ON EDUCATIONAL TOOL. Robert S. Marshall, Automated Weather Source, Inc., Gaithersburg, MD

(J6) 42 J6.11 APPLICATIONS OF SATELLITE IMAGERY AND REMOTE SENSING IN ENVIRONMENTAL/SCIENCE EDUCATION: AN EARTH SYSTEMS SCIENCE APPROACH. John D. Moore, Burlington County Inst. of Technology, Medford, NJ

(J6) 47 J6.12 THE GREENHOUSE EFFECT VISUALIZER: A TOOL FOR THE SCIENCE CLASSROOM. Douglas N. Gordin, Northwestern Univ., Evanston, IL; and R. D. Pea

(J6) 53 J6.13 WHERE IS YOUR DATA? A LOOK AT STUDENT PROJECTS IN GEOSCIENCE. Steven McGee, Northwestern Univ., Evanston, IL

* J6.14 A VISUALIZATION WORKSTATION TO IMPROVE INSTRUCTION IN THE ATMOSPHERIC AND OCEANIC SCIENCES. Steven A. Ackerman, Univ. of Wisconsin, Madison, WI

(J6) 57 J6.15 ANALYSIS AND DISPLAY OF SINGLE AND MULTIPLE DOPPLER RADAR DATA USING GEMPAK AND VIS-5D. Michael R. Nelson, Texas A&M Univ., College Station, TX; and S. Hristova-Veleva, J. W. Nielsen-Gammon, and M. I. Biggerstaff

* Manuscript not available

AUTHOR INDEX

FOURTH SYMPOSIUM ON EDUCATION

A

	PAPER #	PAGE
Abrams, E.	P1.37	139
Achtor, T.	J6.2	(J6)3
Ackerman, S. A.	J6.14	*
Allsopp, J.	P1.20	96
Anderson, J.	P1.28	121
Arnold, T. C.	J1.2	(J1)5
Atangan, J. F. H.	J1.4	(J1)13

B

	PAPER #	PAGE
Bagby, R. C.	P1.35	131
Ballentine, R. J.	1.3	9
Biggerstaff, M. I.	1.11	37
Biggerstaff, M. I.	J6.15	(J6)57
Binkley, M. S.	1.2	3
Birch, S.	P1.21A	152
Blackwell, K. G.	1.7	23
Boylan, R. L.	J1.12	(J1)25
Bremner, S. B.	P1.38	141
Buescher, L.	J6.2	(J6)3
Businger, S.	1.1	1
Byrd, G. P.	1.3	9
Byrne, J. P.	P1.30	125

C

	PAPER #	PAGE
Camarda, R. M.	P1.23	103
Carlson, S.	P1.12	72
Carson, T.	P1.13	78
Ceritelli, M. J.	P1.32	*
Chapman, D. A.	J6.4	(J6)9
Chapman, W. L.	J6.4	(J6)9
Chermack, E. E.	1.3	9
Crawford, K.	P1.8	59
Croft, P. J.	1.2	3
Croft, P. J.	1.6	19
Croft, P. J.	P1.10	68

D

	PAPER #	PAGE
Dillner, D. S.	J1.4	(J1)13

E

	PAPER #	PAGE
Edelson, D. C.	J6.5	(J6)15
Eisman, G. A.	J1.4	(J1)13

F

	PAPER #	PAGE
Ferguson, J.	J1.9A	*
Franks, S.	P1.21A	152

G

	PAPER #	PAGE
Garrett, C. A.	P1.4	50
Geer, I. W.	J1.3	(J1)10
Geer, I. W.	J1.4	(J1)13
Geer, I. W.	1.5	15
Gibson, B.	P1.7	58
Gilmore, M.	P1.29	123
Gomez, L. M.	J6.5	(J6)15
Gordin, D. N.	J6.12	(J6)47
Graewin, R.	J6.2	(J6)3
Graham, S.	P1.15	82
Graham, S.	J6.1	(J6)1
Greenleaf, L. E.	P1.5	54
Greenleaf, L. E.	P1.6	56
Gunderson, C. R.	1.10	34
Gunderson, C. R.	P1.2	44
Guth, P. L.	J1.4	(J1)13

H

	PAPER #	PAGE
Hall, S.	J6.6	(J6)19
Heckman, B. E.	1.7	23
Heckman, B. E.	1.8	25
Heckman, B. E.	1.9	29
Henry, A.-M.	J1.8	(J1)20
Higgins, D. J.	P1.39	144
Higgins, D. J.	P1.40	148
Holle, R. L.	P1.20	96
Hopkins, E. J.	J6.3	(J6)5
Howard, K. W.	P1.20	96
Hristova-Veleva, S.	J6.15	(J6)57
Hutchins, S.	J6.1	(J6)1

I

	PAPER #	PAGE
Ibarra, H.	P1.17	90

J

	PAPER #	PAGE
Janc, N.	P1.27	119
Johnson, J. J.	P1.9	63
Johnson, J. J.	P1.18	93
Johnson, J. J.	P1.28	121
Johnson, J. J.	P1.29	123
Johnson, V. C.	J6.7	(J6)23
Jones, D. W.	J1.4	(J1)13
Jordan, W.	P1.15	82

K

	PAPER #	PAGE
Kahl, J. D. W.	P1.33	*
Kemp, J.	J6.6	(J6)19
Kloesel, K.	P1.15	82
Kloesel, K.	J6.1	(J6)1
Knipp, D. J.	1.7	23
Knipp, D. J.	1.8	25
Koehler, T. L.	1.7	23

* Manuscript not available

AUTHOR INDEX

FOURTH SYMPOSIUM ON EDUCATION

	PAPER #	PAGE
L		
Lans, F.	J6.1	(J6)1
Lee, E. Y.	P1.39	144
Lee, E. Y.	P1.40	148
Lee, J. A.	P1.32A	153
Lees, R. L.	P1.19	94
Levin, J.	P1.37	139
Lopez, R. E.	P1.20	96
Lykens, J.	P1.40	148
Lykens, J.	P1.38	141
M		
MacDonald, M. A.	P1.38	141
MacDonald, M. A.	P1.39	144
Mach, M. A.	P1.9	63
Mach, M. A.	P1.25	111
Maier, A.	P1.32A	153
Malek-Madani, R.	1.10	34
Malek-Madani, R.	P1.1	41
Malek-Madani, R.	P1.2	44
Malek-Madani, R.	P1.4	50
Marshall, R. S.	J6.10	(J6)37
Martinek, C. A.	J1.4	(J1)13
Marwitz, J. D.	P1.34	129
Mazarowski, L.	P1.15	82
McCollum, F.	P1.26	116
McCormick, P. R.	P1.38	141
McCormick, P. R.	P1.40	148
McGee, S.	J6.13	(J6)53
McGregor, K. M.	P1.36	133
McManus, D. E.	J1.4	(J1)13
McPherson, R. A.	P1.8	59
McPherson, R. A.	P1.24	105
Meldrum, G. G.	J1.2	(J1)5
Meldrum, R. G.	P1.38	141
Middleton, R. D.	J1.4	(J1)13
Miller, E. J.	J1.4	(J1)13
Mills, T.	P1.8	59
Moore, J. D.	J6.11	(J6)42
Morrissey, M.	P1.7	58
Mroz, P. J.	J1.1	(J1)1
Murphy, K. A.	P1.22	100
N		
Nelson, M. R.	J6.15	(J6)57
Nguyen, H.	P1.21A	152
Nielsen-Gammon, J. W.	1.11	37
Nielsen-Gammon, J. W.	J6.15	(J6)57
Novak, D. E.	J6.4	(J6)9
P		
Pani, E.	1.1	1
P (continued)		
Pea, R. D.	J6.5	(J6)15
Pea, R. D.	J6.12	(J6)47
Peppler, R. A.	P1.14	80
Postawko, S.	P1.7	58
Poteat, E. H.	P1.11	70
Preyer, J. A.	P1.1	41
R		
Ramamurthy, M. K.	J6.5	(J6)15
Ramamurthy, M. K.	J6.6	(J6)19
Reinke, B. C.	P1.14	80
Richards, S. J.	J1.5	(J1)17
Rodi, A. R.	P1.34	129
Ross, T. F.	J6.8	(J6)29
Ruscher, P.	P1.15	82
Ruscher, P.	J6.1	(J6)1
Ryan, R. T.	J1.11	(J1)22
S		
Samson, P. J.	J1.9A	*
Schwartz, M. D.	P1.36	133
Smith, D. R.	1.10	34
Smith, D. R.	P1.1	41
Smith, D. R.	P1.3	47
Smith, D. R.	J1.3	(J1)10
Smith, D. R.	J1.4	(J1)13
Smith, P. J.	1.1	1
Smith, P. J.	1.4	11
Smith, P. L. K.	P1.3	47
Smith, W. L.	J6.2	(J6)3
Snow, J. T.	J1.3	(J1)10
Snow, J. T.	J1.7	*
Solis, E.	P1.31	*
Spangler, T. C.	J6.7	(J6)23
Sridhar, M.	J6.6	(J6)19
Stadler, S. J.	P1.8	59
Stamm, A. J.	1.3	9
Steele, C. J.	P1.41	150
Steremberg, A.	J1.9A	*
Straw, S. A.	J6.9	(J6)34
Strong, A. E.	J1.4	(J1)13
Strong, B. M.	P1.2	44
T		
Tessmer, M. A.	1.6	19
Thomson, E. S.	P1.39	144
Thomson, E. S.	P1.40	148
V		
Vavrek, R. J.	P1.20	96

* Manuscript not available

AUTHOR INDEX

FOURTH SYMPOSIUM ON EDUCATION

V (continued)

	PAPER #	PAGE
Vieira, M. E. C.	J1.4	(J1)13
Vincent, D. G.	1.4	11

W

	PAPER #	PAGE
Walker, S. H.	J1.6	*
Walters, Sr., K. R.	J6.9	(J6)34
Warthan, H. P.	J1.12	(J1)25
Weinbeck, R. S.	1.3	9
Weinbeck, R. S.	1.5	15
Weinbeck, R. S.	J1.3	(J1)10

W (continued)

	PAPER #	PAGE
Wilhelmson, R. B.	J6.5	(J6)15
Wilhelmson, R. B.	J6.6	(J6)19
Williams, Jr., A.	P1.10	68
Williams, C. A.	P1.39	144
Williams, C. A.	P1.40	148
Wojtowicz, D.	J6.6	(J6)19

Z

	PAPER #	PAGE
Zebransky, J.	1.1	1

---

* Manuscript not available

1.1

THE BACHELOR'S DEGREE IN ATMOSPHERIC SCIENCE

- REVISION OF THE 1987 AMS STATEMENT

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A. INTRODUCTORY REMARKS

The AMS Board on Meteorological and Oceanographic Education in Universities (BMOEU) has been charged with revising the AMS statement on the Bachelor's degree in atmospheric science. The last statement was adopted on October 2, 1987 (see Bulletin of American Meteorological Society, December 1987, p. 1570). The BMOEU in turn appointed a subcommittee, composed of the co-authors named above and chaired by the first author, to develop a revised statement. This paper is a report on the status of the subcommittee's deliberations. The revised statement, which follows, contains some features carried over from the 1987 statement; some found in the new National Weather Service employment standards; and some added to reflect the differing career paths of contemporary atmospheric science undergraduates.

B. PROPOSED STATEMENT

1. Introduction

This statement describes the *minimum* curricular composition, faculty size, and facility availability recommended by the American Meteorological Society for an undergraduate degree program in atmospheric science (meteorology). Its purpose is to provide advice to university faculty and administrators who are seeking to establish and maintain undergraduate programs in atmospheric science and guidance to prospective students who are exploring their educational alternatives.

It should be noted that, while many similarities exist, the curricular composition described below does not conform to the federal civil service requirements for employment as a meteorologist. Rather, this statement recognizes that contemporary education in atmospheric science must include fundamental background in basic atmospheric science and related sciences and mathematics, while at the same time providing flexibility for students to pursue alternative career paths.

2. Attributes of Bachelor's Degree Programs

a. General objectives

The objectives of a Bachelor's Degree program in atmospheric science include one or more of the following:

1) in-depth study of meteorology to serve as the culmination to a science or liberal arts education;

2) preparation for graduate education; or

3) preparation for professional employment in meteorology or a closely related field.

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b. Course offerings

A curriculum leading to the degree Bachelor of Science (or Bachelor of Arts) in Atmospheric Science should contain:

1) At least 24 semester hours (or 36 quarter hours) of credit in atmospheric science that includes

    i) 12 semester hours of lecture and laboratory courses, with calculus as a prerequisite or corequisite, in atmospheric thermodynamics and dynamics and synoptic meteorology that provide a broad treatment of atmospheric circulations ranging from large scale to mesoscale;

    ii) three semester hours of atmospheric physics with emphasis on cloud/precipitation physics and solar and terrestrial radiation;

    iii) three semester hours of atmospheric measurements, instrumentation and remote sensing, including both lecture and laboratory components; and

    iv) an additional six semester hours in atmospheric science electives;

2) calculus through ordinary differential equations in courses designed for majors in either mathematics, physical science, or engineering;

3) a one-year sequence in physics, with laboratory, with calculus as a prerequisite or corequisite;

4) a course in chemistry appropriate for physical science majors;

5) a course in computer science appropriate for physical science majors; and

6) a course in statistics appropriate for physical science majors.

As in any science curriculum, students should have the opportunity and be encouraged to supplement these minimum requirements with additional course work in the major or any of the supporting areas, including not only courses in the basic sciences, mathematics, and engineering, but also courses designed to broaden the student's perspective on the environmental sciences (e.g., hydrology, oceanography, and solid earth sciences) and science administration and policy making. Also, students should be urged to give considerable attention to course work or other activity designed to develop effective communications skills, both written and oral. Further, academic programs are urged to provide the flexibility that may be required to accommodate the diverse educational and cultural backgrounds of contemporary students.

Finally, as noted in the Introduction, the curriculum described above does not conform exactly with federal civil service requirements. However, it is recommended that courses required to fulfill federal employment requirements, even if not required, be made available. Furthermore, if the offering of such courses is not consistent with the educational objectives of the program, then the institution has an obligation to inform prospective students that the completion of their undergraduate degree will not fully qualify them for entry-level employment in federal agencies.

c. Faculty attributes

There should be a minimum of three full-time regular faculty with expertise that is sufficiently broad to address the subject areas identified in 2b.1) above. The faculty role should extend beyond traditional teaching and research to providing academic counseling to students with diverse educational and cultural backgrounds.

d. Facilities

There should be coherent space for the atmospheric science program and its students. Contained within this space should be access to real-time and archived meteorological data through computer-based data display systems, the availability of applications software suitable for the diagnosis of dynamical and physical processes in the atmosphere, and facilities for studying atmospheric observation and measurement techniques. Further, course requirements should include components which utilize modern departmental and/or institutional computer facilities.

1.2

METEOROLOGY'S EDUCATIONAL DILEMMA

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1. INTRODUCTION

The pedagogical philosophy of college education has been to provide undergraduate students with basic theory for use in the identification and solution of new problems. However, a growing number of state legislators and policy makers now question whether college faculty are more concerned with research, publication, graduate education and their own professional activities than undergraduate education (Layzell, 1992). It is increasingly perceived (e.g., Barnett, 1992 and Greenberg, 1993) that undergraduate teaching is secondary to these and often lacking in sufficient application and practicum opportunities for undergraduate students.

Atmospheric science is particularly affected by these perceptions as many findings and applications from the field are directly related to the general population's daily activities. Although some of these issues have been addressed as they pertain to meteorological education (e.g., Dutton, 1992 and Fritsch, 1992), a much finer examination is warranted. For example, rapid changes in theory, applications, and technology demand constant revision and updating of the theory and applications taught to undergraduate students. If this is not routinely done, then education becomes a superficial study of the various aspects of a field rather than a detailed study of its significant problems and concepts.

2. HISTORICAL CONTEXT

Many present day meteorology undergraduate programs were fashioned after that of the California Institute of Technology. The program of study there was established in 1933 in response to commercial and military aviation operational needs (Lewis, 1994) and therefore had strong synoptic and climatic components. However, rapid advancement in the field of meteorology in terms of theory (e.g., quasigeostrophic flow; synoptic, mesoscale, and stratospheric dynamics), applications (e.g., air pollution meteorology), and technology (e.g., increased computational power, satellites, and doppler radar) since that time have changed and greatly expanded the role of meteorology.

Many meteorologists are now working as environmental consultants, broadcast meteorologists, or as consultants in applied meteorology and climatology. Since 1970 the number of private sector meteorologists has increased 20% with an equivalent decrease in government and university positions (Dutton, 1992). Specialization in agriculture, business, forensics, and industrial applications now account for 35% of all meteorologists. The proliferation of alternative meteorology careers, in conjunction with the modernization of the National Weather Service, and the automation afforded by improved technology and artificial intelligence, requires a reassessment of undergraduate meteorology education in terms of its content and delivery.

3. EDUCATIONAL DILEMMA

Despite acknowledgement of advancements in the field and recognition that changes in course content and delivery may be appropriate, traditional meteorological education has remained mostly static with regard to the principles taught and the required coursework. Most undergraduate meteorology programs offer courses in dynamic meteorology, meteorological instruments, synoptic meteorology, structure of the atmosphere, and meteorological laboratories and remain remarkably similar to the original program offered by the California Institute of Technology.

Yet the field continues to change and the knowledge considered necessary to work in metetorology continues to expand. This presents meteorology with an

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educational dilemma: How do we adequately prepare future meteorologists for their careers using traditional approaches as those approaches and the wealth of meteorological information, theory, and applications change? Although individual and group attempts have been made to update, revise, and revitalize undergraduate meteorological education the amount of information that meteorologists must assimilate continues to grow making it more difficult to properly prepare new meteorologists. This is analogous to history instruction in that either old materials must be replaced by new or more superficial coverage must be given to all material.

In considering meteorology's educational dilemma it is first necessary to re-evaluate the nature of basic education and training with regard to employer requirements and user needs. Such an assessment, and an analysis of its component issues, is necessary for the development of solutions to the dilemma. Fritsch (1992) has addressed some of these issues, such as the costs of making changes to university curricula, in outlining three solutions that have been offered: requiring a five year meteorology Bachelor's Degree, making the study of meteorology graduate level only, or the development of subdiscipline specialties within meteorology.

However, before these may be considered, the nature of meteorology's educational dilemma must be definitively characterized. This may be accomplished through an evaluation of the appropriateness of current educational requirements with regard to employer needs and based on current and future changes in the field of meteorology. In this way the effectiveness of undergraduate meteorological education, and continuing education and professional training, may be evaluated. Only then can possible approaches to solve any problems be outlined and properly reviewed based on their merits and cost-effectiveness. In this way an informed plan of action can be developed to ensure the field's viability and its ability to produce qualified meteorologists.

3.1 Federal Requirements

Educational requirements for meteorologists established by the federal government, known as the x-118 Qualification Standards, were originally based on the National Weather Service's mission of forecast and warning service to the general public. These requirements include 20 semester hours of meteorology with a minimum of six hours in weather analysis and forecasting, six hours in dynamic meteorology, differential and integral calculus, and six hours in college physics. These requirements have been used as the basis for meteorology programs at colleges throughout the United States and serve as the basis for a Bachelor's Degree in meteorology.

With the recent modernization of the National Weather Service, changes in the requirements are being considered so as to include six hours of dynamics/thermodynamics (with calculus), six hours of analysis and prediction of weather systems, three hours of physical meteorology and two hours of remote sensing of the atmosphere and/or instrumentation. In addition, nine hours from statistics, chemistry, aeronomy, computer science, or other related courses would be required. This requirement reflects the fact that future meteorologists are expected to have backgrounds in environmental science, engineering, systems education (Zevin and Carter, 1994) and will work in a "laboratory for testing and refining applied research" (Carter, 1994).

3.2 Undergraduate Meteorology Programs

The federal educational requirements have traditionally been used by universities as the basis for a "minimally sound" undergraduate program. Both existing and proposed (Smith et al., 1994) curriculum requirements for a Bachelor's degree in atmospheric science are similar to those of the federal government. However, some differences appear when other coursework (e.g., computer science) or total credit hours are considered (e.g., synoptic and dynamic). The differences, although largely related to institutional requirements for a degree granting program, do illustrate a difference of opinion on the preparation of meteorologists and has some intriguing characteristics.

Although the majority of schools offering meteorology (1992 AMS Curricula Guide) meet both the current and proposed standards, many lack a physical meteorology component or instead offer a series of specialized courses on topics from this field, or which offer professional experiences (e.g., see Hallett et al., 1990, Lewis and Maddox, 1991, Orville and Knight, 1992, Navarra et al., 1993, and Hindman, 1993), or which are applied in nature (e.g., air pollution meteorology, applied meteorology, et cetera). Although these provide evidence that university meteorology programs have attempted to remain current in the field, and do attempt to provide a wide range of knowledge and experience to students, it indicates inconsistent meteorological preparation.

3.3 Continuing Education and Training

The proliferation and extensive use of continuing education and training courses in meteorology is due to increased specialization within the field, the development of new findings and techniques, and the increased amount of knowledge meteorologists are expected to acquire. Education and training workshops (such as on the use and interpretation of doppler radar) are held by NCAR/UCAR, private industry, the National Weather Service, and organizations such as the AMS and the NWA to meet this need. The Cooperative Program for Operational Meteorology, Education and Training (COMET) has developed several educational programs, including multimedia learning modules, to assist in this task.

Although a necessary and important component of the field, this additional training and education raises questions as to the preparation level of new meteorologists, the accreditation of undergraduate programs, and the assignment of graduate or continuing education credits. In the first instance, it is implied that new meteorologists have not been, or are no longer, adequately prepared for their jobs. In the second situation, the issue of accreditation arises due to inconsistent preparation and suggests that a formal standardization of meteorology programs, in terms of course content and delivery, is necessary. In the last instance, those with specialized training do not necessarily receive credit towards graduate education commensurate with their experience.

4. UNDERCURRENTS

Even though traditional meteorological instruction has produced leading researchers, academicians and operational forecasters, there is a growing body of both anecdotal and hard evidence that traditional methods are no longer adequate. In private discussions among professional meteorologists, and from Internet correspondence amongst undergraduate and graduate meteorology students, there is a sense of uneasiness and dissatisfaction over the ability of current education and training programs to meet the needs of today's and tomorrow's meteorology careers or those of the students.

4.1 Faculty Perspectives

In academia, the lack of quality pre-college preparation, the degradation of college standards, the out-dated nature of some instructional techniques and texts, and the lack of a practical context or practicum (e.g., Slakey, 1994) have all been cited as contributing factors to both this perception and the real problems observed.

Summary results (Mooney, 1994) of a global survey of scholars by the Carnegie Foundation indicate that although 79% of United States college faculty believe young people are capable of completing secondary education, only 20% believe that undergraduates are adequately prepared in written and oral communications skills and only 15% believe them prepared in mathematics and quantitative reasoning.

4.2 Student Perspectives

An informal sampling of students who have graduated from various programs within the last five years revealed that most had a high regard for their overall college preparation, particularly that provided in synoptic classes and the emphasis on the use of computers. These students were currently employed by the National Weather Service, private consultants, or other agencies and are therefore indicators of the current effectiveness of meteorological education.

However, more than three-fourths of these students felt that their calculus courses focused more on theory than application, that the dynamics sequence was too mathematical (and not applied sufficiently), and that career counseling in meteorology was severely lacking. As most of these students are recently new employees, they suggested that current students be given an increased emphasis on dynamic-synoptic meteorology connections, applied meteorology (hydrology in particular), research applications, interdisciplinary relationships, practical training, communications, and career perspectives.

4.3 Preliminary Evaluations

Some quantification of these problems has been made through various AMS Education symposia (Smith and Snow, 1993) and conferences on School and Popular Meteorological and Oceanographic Education (Snow and Smith, 1990; Kern et al., 1993; Newman and Smith, 1994). However, these have focused primarily on pre-college and outreach efforts of universities and other agencies. Department chair meetings (Takle, 1987; Takle, 1989; Vincent, 1991) have studied and assessed curriculum design.

However, changes and evolution of the field continue to intensify meteorology's educational dilemma making it imperative that solutions and strategies be developed now. For example, in geography education Downs

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(1994) has pointed out that six education questions must be answered in order to formulate a proper response to changes and advancements in the geographic field. Applying these to meteorology: What is the character of expertise in meteorology? What is its origin? What are its components? How is it developed? By what procedures is it identified and assessed? How is it successfully taught/learned?

5. A PLAN OF ACTION

Based on informal conversations, and the reviews of Dutton (1992) and Fritsch (1992), a list of options available to solve meteorology's educational dilemma (see Table 1) may be summarized as follows. The first option would be to expand meteorology to a five year non-thesis (Master's Degree in applied meteorology) program. This would allow for the retention of all old and new material in class. The second option would be to offer meteorology at the graduate level only. This would place an emphasis on preparation in math and physics prior to the study of atmospheric science. A third option is to develop training specialties within meteorology to provide enhanced, although limited, career preparation.

A fourth option is to provide only theoretical meteorology so that students may be prepared for any career path. This would eliminate any practical meteorology experience or training and defer these to the workplace. A fifth option is to require students to complete professional internships to obtain practical experience. This option provides both a "qualifying exam" and career counseling for future employees. A sixth option is to revise the pedagogy of meteorology with regard to requirements, certification, and methods of instruction. This would require an identification of any problems in instruction (i.e., course curriculum, content, and delivery), the development of strategies to correct or remove these, and the implementation of methods to achieve the same.

Each of these options contain a variety of pros and cons which must be fully examined before a clear plan of action can be developed. Therefore, in order to properly address meteorology's educational dilemma it is first necessary to quantify current opinions of the professional and student communities with regard to a meteorologist's preparation to perform his or her job. Therefore, a survey of all meteorologists is in order to provide both qualitative (opinions) and quantitative (summative) assessments and evaluations of the ability of the field to meet job needs and the ability of meteorologists to complete tasks and solve problems associated with various career opportunities.

Towards this end, a sample questionnaire has been developed for completion by employers, educators, employees, and undergraduate and graduate students. Each questionnaire respondent will be asked to provide personal identification in order to weight the significance of the responses and to assess opinions according to the background of the meteorologist responding (e.g., private consultant, professor, broadcaster, et cetera). Other sections will ask for specific information and solicit comment on various aspects of meteorology's educational dilemma and are designed with specific meteorologists in mind (i.e., employer, employee, et cetera). Some respondents may complete questions from several sections of the survey if they are in a position of multiple responsibilities (e.g., employer and employee).

6. AN OPEN FORUM

Before the proposed survey is distributed, we ask all members of the meteorological community to contact us with regard to comments and suggestions towards its revision and distribution. We feel that this is an essential step to ensure that all appropriate questions are asked, all members are asked, and that any biased questions, or those which may be misinterpreted, may be revised. Once completed, the survey will be distributed to all meteorology departments, National Weather Service Forecast Offices, those listed in the AMS Member Directory, and local AMS and NWA chapters to ensure adequate distribution and response.

In this way a wide range of responses will come from employers, employees, instructors, and students in various situations. This approach will provide the necessary information for the proper assessment of current meteorological education and preparation, its appropriateness, and information on which to base strategies for refining future meteorological education. It will also provide crucial information for debate of the options available for solving meteorology's educational dilemma.

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Table 1. Six potential options for addressing meteorology's educational dilemma and some of the pros and cons associated with them.

Option	Description	Pros	Cons
A	Expand undergraduate degree to a 5 year program	Improved preparation Currency in field	Cost and logistics Reduced enrollment
B	Offer meteorology at the graduate level only	Improved preparation	Reduced enrollment
C	Develop specialty training within Bachelor's Degree	Currency in field Meet user needs	Insufficient student preparation Confusion among users
D	Provide only theoretical education to undergraduates	Research preparation Currency in field	No practical experience or context Unpopular in higher education
E	Require professional internships of all students	Practical experience Career development	Cost and logistics Standardization of experience
F	Revise pedagogy of meteorological education	Currency in field Improved preparation Practical experience Career development Meet users needs	Over-standardization of curricula Assessment of needs necessary Cost to implement changes

1.3 INVOLVEMENT OF UNDERGRADUATE METEOROLOGY STUDENTS IN FACULTY RESEARCH PROJECTS

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1. INTRODUCTION

Faculty in undergraduate meteorology programs face a difficult challenge attempting to maintain active involvement in research in the face of heavy instructional loads. The National Science Foundation's (NSF) Research in Undergraduate Institutions (RUI) program is designed to support enhancement of the research environment and the integration of research into the science and engineering educational offerings at such institutions. An important component of this program is the involvement of undergraduates in research projects. In 1989, the State University of New York (SUNY) Colleges at Brockport and Oswego were awarded a RUI grant from the NSF Atmospheric Sciences Division. This enabled the continuation of field research and numerical modeling investigations of lake-effect snowstorms. A second RUI grant was awarded in 1993. This paper describes the involvement of undergraduate students in the RUI grant and several other research projects at SUNY Brockport and SUNY Oswego.

2. RESEARCH ACTIVITIES

Undergraduates have participated in field projects working on mobile sounding crews or as nowcasters. Students were chosen based on background course work and previous field experience. Mobile sounding crews received extensive training in the operation of sounding systems, and nowcasters were required to become familiar with nowcasting and observation techniques as well as the computer archival of meteorological data.

Three lake-effect field projects involving undergraduates have been conducted: a pilot study during the winter of 1987/88, the Lake Ontario Winter Storms (LOWS) study in 1990, and a follow-up project during the winter of 1991/92. Faculty/student mobile sounding teams were dispatched to targeted locations to sample the environments associated with lake-effect snowbands on the southern and eastern shores of Lake Ontario, an area far removed from conventional National Weather Service sounding locations. These soundings were used in subsequent case study analyses and in the initialization and verification of model simulation studies. Trained students occupied nowcast centers, taking observations and monitoring conditions on a continuous basis during most of the operational periods. Student nowcasters were in frequent communication with field project teams, imparting crucial information which played an important role in the development of deployment strategy.

Several students have been involved in the case study analyses of the field project data. Their primary work has been in data reduction, sounding analysis and the complementary synoptic and mesoscale analysis efforts. Undergraduates have also had some peripheral involvement in analysis and interpretation of remotely-sensed satellite and Doppler radar data. Several of the case studies and results have been included in courses on weather forecasting and mesoscale meteorology.

Other students have participated in the numerical simulation efforts. These students were

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Table 1: Summary of student outcomes subsequent to participation in RUI-related activities (1988-1994).

Total	Undergrad students	Grad School	NWS	Military	Private	Non-meteorology
49	14	17	7	4	5	1

selected on the basis of their academic preparation (e.g. synoptic meteorology course work was required), computing experience, and general interest in lake-effect snowstorms. After preliminary training, students assisted with preparation of initial detests for the model, analysis and interpretation of the model output, and in some cases, studies of the sensitivity of the model results to initial data, boundary conditions, and grid resolution. The analysis of model output helped students to better understand the relationship between mesoscale convergence and precipitation, and the effect of large-scale parameters on the rate of development of snowband circulations. Students were able to compare model output inside and outside snowbands with data collected by field teams. They also gained experience using Fortran programs and graphics applications. Recently, students have been involved in an effort to expand the model domain to include all of the Great Lakes, in order to study multiple-lake interactions during cold air outbreaks.

Case study analyses and model simulation efforts have resulted in at least ten publications (journal articles, conference proceedings) of which students were co-authors. Draft manuscripts were prepared by the lead author, who was usually a faculty member. In many cases, copies were distributed to the undergraduate co-authors for comment. Where appropriate, the student input was then incorporated into the revised version prior to final submission for publication.

Undergraduates have also played active roles in recent field projects unrelated to the RUI program. These include an FAA-sponsored aircraft deicing fluid study, tethersonde and radiosonde observations and a modeling study of land- and lake-breeze circulations.

3. STUDENT OUTCOMES

As of August, 1994, 49 undergraduates have been involved in RUI-related research activities, as indicated in Table 1. Of the 35 who have since graduated, 17 have chosen to further their education through graduate study, and 16 are employed in meteorology or a related field. Of the 16 employed in meteorology, seven are employed with the National Weather Service, four are employed in the military, and five are employed by private industry. In addition, nine of these student assistants have co-authored professional papers (nine conference papers and one refereed journal article) with faculty mentors. Three students have participated in the National Center for Atmospheric Research's summer employment program, and one participated in an NSF-sponsored Research Experiences in Undergraduate (REU) program at the University of Michigan.

4. CONCLUSIONS

The RUI experience has enabled faculty to pursue research on Great Lakes winter storms, particularly lake-effect snowstorms. The extensive collaboration of investigators from different institutions who possess a variety of backgrounds has enabled a significant and beneficial research effort.

We believe that the success enjoyed by students who have been involved in RUI activities is testimony to the value of a significant research involvement in the undergraduate meteorology educational experience. Students have been a crucial component in the success of our RUI efforts. They, in turn, have gained valuable hands-on experience working with state-of-the-art field research equipment. In addition, they have become acquainted with observational and modeling research methods, opportunities that are often lacking in meteorology programs of undergraduate-only institutions. Several have co-authored professional papers dealing with their research. These experiences will continue to serve them well as they pursue graduate study and careers in the atmospheric sciences.

5. ACKNOWLEDGMENTS

Much of our research activity has been funded by NSF RUI grants ATM-8914546 and ATM-9224384. The LOWS project was also funded by Niagara Mohawk Power Corporation and the Great Lakes Research Consortium. Some student support has been obtained through the Ronald E. McNair and the Collegiate Science and Technology Entry programs. We especially want to thank all of the students for their tireless efforts which made a significant contribution to the success of the program.

1.4

CREATING AND MAINTAINING ENTHUSIASM FOR THE UNDERGRADUATE MAJOR

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1. INTRODUCTION

One of the more rewarding experiences for the undergraduate meteorology major is to have an opportunity to take part in one or more activities in his/her chosen field while he/she pursues a degree. Such opportunities can create and maintain the student's enthusiasm for the atmospheric sciences by getting him/her involved early in their careers. Of course, this also requires a mutual interest and dedication on the part of the faculty. The purpose of this paper is to suggest a variety of ways in which the student's enthusiasm and involvement in meteorology can be initiated and/or maintained during his/her undergraduate years. We have chosen to group these opportunities into four general categories: (1) educational; (2) professional; (3) employment and (4) research. We realize, however, that many opportunities may cross over into two or more categories. We also realize that there may be additional opportunities/activities which we have mistakenly omitted. Admittedly, most of the examples given in this paper are those we have experienced at our home institution, and we are quick to acknowledge that it may not be feasible for some of the opportunities to be pursued at every undergraduate institution.

2. EXAMPLES

a. Educational

Not surprisingly, most of the opportunities fall into this category. One way to immediately involve a new student is to offer/require a freshman level course to be taken, ideally, in the first semester/quarter. This course could be an introductory "Survey of Meteorology" type of class, without any mathematics or science background required; however, it is often preferable to delay an introductory meteorology course (intended for majors) until after the student has acquired some minimal scientific knowledge. In the early 1970's we introduced into our B.S. curriculum a first semester course titled, "Profession of Meteorology". The course meets once a week and is team taught in the sense that each faculty member in atmospheric science and related disciplines discusses a timely topic in his/her specialty area. A discussion of career opportunities and a tour of our departmental computing facilities are also included. Attendance is the only requirement. The purpose of this course is twofold. It allows the incoming student an opportunity to see what meteorology really is all about, and it exposes the student to each member of the faculty. With regard to the former, the course is required for majors, but is open to any student who might have an interest in meteorology or be undecided about a major. A typical enrollment is 30 students, a number which is interesting to compare to the average size of our atmospheric science senior class which is 10.

Another way to stimulate and maintain enthusiasm among undergraduate students is to have some kind of computer-based instructional facility. Most students are fascinated by weather displays on a computer screen, and for them to be able to produce such displays is generally quite exciting. The availability of modern personal computers and workstations makes it possible to simulate a host of atmospheric phenomena and processes. For example, it is possible to recreate the growth of a cloud from cumulus to cumulonimbus and to depict moving weather systems. We realize that the cost of a computing system can be a deterrent for some programs, but a wide variety of systems are currently available.

A third type of activity which generally promotes enthusiasm among students (and faculty and staff as well) is a weather forecasting "game". This activity not only has instructional value, but also creates a challenge and even some entertainment among the players. For example, the student has an opportunity to make a better forecast than the professor. At Purdue, we introduced a forecast game about 20 years ago. Typically, about 20-30 players participate. Over the years we have kept statistics from the top ten players each semester, and they are generally competitive with NWS predictions. With regard to 24-h temperature forecasts, for example, our errors for the local region have been decreasing at approximately the same rate as those from MOS. Presently, the consensus of the best players shows min/max temperature errors of about 3.5°F.

Still another way to help students maintain an interest in their undergraduate education is to make them aware of opportunities for financial gain. Financial support is available in a number of ways, ranging from rewards for academic excellence or research potential to hourly paid employment. Employment opportunities will be discussed in section 2c and research opportunities in section 2d. For now, we shall focus on opportunities that are available for educational stipends. There are many types of scholarships that are awarded each year to students who have excelled academically. In the field of atmospheric science and related disciplines, the American Meteorological Society recently has been successful in acquiring support from several leading environmental science and service corporations for scholarships to be awarded to worthy students. These AMS/Industry Scholarships now number eleven and provide support for students in their junior and senior years. A description of the awards, the names of the corporations offering the scholarships, and the list of students who were awarded scholarships for 1994-95, are given in the Bulletin of the AMS in the July 1994 issue.

It was noted in the Introduction that creating and maintaining student enthusiasm requires a mutual interest and dedication on the part of the faculty. One of the best ways that faculty can motivate students is through excellence in teaching. Clearly, some faculty are more blessed than others when it comes to formal classroom teaching, but anyone who is genuinely interested in providing the best possible education for the undergraduate student can be an effective teacher. Another way that faculty can involve themselves in maintaining a high level of interest among students is to seek ways of establishing personal contact. Two examples which come to mind are inviting students to your home for a social event and participating in the student counseling process. With regard to the latter, our faculty at Purdue has always taken an active role in counseling undergraduate majors, with each faculty member acting as the academic advisor for about 5-10 students. Our students seem to appreciate the opportunity to interact one-on-one with the faculty.

b. Professional

One way to create and maintain enthusiasm among undergraduates, as well as to promote early professionalism, is to encourage them to become student members of the AMS. This allows them to receive, at a reduced rate, the Bulletin of the AMS and other AMS subscriptions, and thereby stay in tune with the activities of their professional society, as well as promote its growth.

Another way to fulfill professional enthusiasm is to participate in student club activities. In some instances, this may involve a student chapter of the AMS, while in others it may involve a group of interested and motivated meteorology students. At Purdue we have the latter. In 1990, a small cadre of students approached the faculty with the idea of forming a club. They were encouraged and, primarily on their own, proceeded to form the Purdue University Meteorology Association (PUMA). Presently, there are about 15 active members and among their activities are helping with freshman orientation, maintaining a tutoring list, hosting speakers, going on trips/tours to meteorological facilities (e.g., NWS and TV stations), and holding social events.

Still another way to retain student interest is to make it possible for them to attend professional meetings. In recent years, the AMS has been very active in this regard by providing financial assistance for undergraduate (and graduate) students to attend the Annual Meeting. For this privilege, the students usually perform some duties at the Meeting. Also, the institution from which the student comes is expected to share in the cost of sending the student to the Meeting. Of course, another way of supporting a student's attendance at a meeting or scientific conference is through research grant funds. Although a rare opportunity for most undergraduates, it may be quite appropriate for students with research grant assistantships or for those engaged in their own research (see 2d).

c. Employment

Employment opportunities are one of the factors students consider when selecting a particular discipline, but career decisions are not within the scope of this paper. Instead, we focus on examples of employment opportunities that can provide the student with financial support and simultaneously stimulate his/her interest in meteorology. One way to accomplish this is to create departmentally-supported positions such as work study or professorial assistantships. This could also include research-supported positions. In either case, the student normally would work under a professor's guidance on some type of research project. Frequently, the student, given this opportunity, will choose to conduct some individual research. In this case there is overlap with the opportunities discussed in section 2d. Another way to stimulate a student's enthusiasm is through cooperative programs with government or industry. These programs generally consist of alternating school terms with employment after the student has completed the sophomore year. The advantages for the student are experience and financial support, while the government or industrial organization gains labor from an enthusiastic student. Another potential advantage for both the student and the cooperative organization is that the experienced student may eventually gain full time employment with the organization. Of course, students who elect a cooperative program will extend their collegiate career by one or more years. Yet another possibility is the growing number of government and industry summer internships. These are attractive because they provide summer income and professional experience without extending the time required to complete the degree.

d. Research

One of the ways to create and maintain an undergraduate's enthusiasm is to involve him/her in a research project. Opportunities exist to seek federal funding for undergraduate research, especially when combined with an instructional program. For example, the National Science Foundation offers competitive grants in Research for Undergraduate Instruction (RUI). A successful program that was funded through one of these grants was the North Dakota Thunderstorm Project conducted in the summer of 1989 under the direction of Professor Harold Orville.

A more modest way to involve students in research is to encourage them to undertake their own research project and, if possible, provide them with an undergraduate assistantship with a small stipend. At Purdue, we created an Undergraduate Honors Program in our department in 1977. Since that time, 22 meteorology majors (~ 10% of our total number of graduates) have completed this program, and 3 are currently enrolled. One of the requirements for this program is to write and give an oral presentation of a B.S. thesis. Nearly all of the students who participated in this program proceeded on to graduate school, where they found that the opportunity to work with a research group and to gain scientific writing experience were invaluable.

3. RECOGNITION

Finally, there is nothing more rewarding to a student than personal recognition for his/her endeavors/accomplishments. In this context, one way to promote enthusiasm among deserving students is to nominate them for awards. This can be done at the departmental level, the university level and at the national level. An example of the latter is to nominate worthy students for the AMS annual scholarship awards. These include the Howard T. Orville, Howard H. Hanks, Paul H. Kutschenreuter, Dr. Pedro Grau, and the AMS 75th Anniversary Scholarships, and the Father James B. Macelwane Award for the best written original paper. Since 1978, we have nominated numerous students for these awards and have been fortunate to meet with very good success. As an example, approximately one-half of our B.S. Honors theses (mentioned above) have been selected for Macelwane Awards.

4. SUMMARY

We have attempted to suggest some ways that can be used to create and maintain a high level interest and enthusiasm among undergraduate meteorology majors. A list of those examples discussed in this paper is given below. As noted in the Introduction, this list is by no means all-inclusive, and is based primarily on our experiences at Purdue.

i. incorporate a freshman level course into the curriculum

ii. have a computer-based instructional facility

iii. promote a weather forecasting game

iv. make students aware of scholarship opportunities (e.g., AMS/Industry Scholarships)

v. have faculty strive for excellence in teaching

vi. have faculty participate in the counseling process

vii. encourage students to apply for AMS membership

viii. suggest involvement in an AMS student chapter or meteorology club.

ix. provide motivation for students to attend professional meetings

x. create departmentally or research-supported positions

xi. develop cooperative programs with government and industry

xii. encourage summer internships

xiii. involve students in a sponsored research project

xiv. institute an Honors Program which requires a thesis

xv. submit deserving student's names for awards

1.5 WEATHER EDUCATION AT THE INTRODUCTORY COLLEGE LEVEL

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1. INTRODUCTION

The American Meteorological Society (AMS), in cooperation with the U. S. National Weather Service (NWS)/National Oceanic and Atmospheric Administration, is conducting an Undergraduate Faculty Enhancement Project, supported by the National Science Foundation, for instructors of introductory courses with significant weather content. The purposes of the project are to (a) provide renewal and updating experiences that focus on the recent advances in operational meteorology and atmospheric research, (b) make available existing and participant-developed laboratory and other student learning materials that emphasize the processes by which the workings of the atmosphere are sensed, analyzed and predicted on a real-time basis, and (c) acquaint participants with the instructional and research potential (faculty and student) of the meteorological data and information bases available via a variety of electronic information services.

2. NEED

While the AMS' Project ATMOSPHERE has been operating for several years to improve weather education at the pre-college level, and University Corporation for Atmospheric Research members, associates, and others offer undergraduate major and graduate programs for professional-level education, a review of geoscience and geography program listings indicates that approximately 80% of the introductory college level courses with significant weather content for the general student are taught by instructors holding degrees in fields other than meteorology. The National Science Foundation estimates that 60% of pre-college teachers also receive whatever science course backgrounds they have in two-year college programs. This implies that under-prepared undergraduate faculty at predominantly two- and four-year institutions teach the overwhelming majority of all students taking introductory-level weather and weather-related courses offered in the United States. The AMS' Undergraduate Faculty Enhancement project was conceived to assist these undergraduate faculty members to provide the best possible courses in this exciting and important area of the sciences. It is particularly crucial in that teachers-in-preparation will be faced with the National Standards calling for the teaching of weather topics at all levels from K-12.

3. WORKSHOP

The project conducted the first undergraduate faculty enhancement workshop at the National Weather Service Training Center in Kansas City, MO, from July 25 - August 5, 1994. This workshop was held in conjunction with the Project ATMOSPHERE workshop routinely held for pre-college teachers to aid in attracting the highest quality presenters of the National Weather Service and other agencies involved in the atmospheric sciences. Twenty-four faculty from 17 states attended. Table 1 shows the demographic breakdown of participants. Table 2 gives the background educational training of the participants, none having earned degrees in the atmospheric sciences.

The intensive two-week workshop included lectures, group discussions, hands-on laboratories and fieldtrips. The focus of all the sessions was the current state of atmospheric sensing, analysis and forecasting. The workshop was organized and conducted by Robert Weinbeck, Ira Geer, Joseph

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Moran, University of Wisconsin-Green Bay, and Katy Ginger, AMS Education Office. Also assisting with instructional sessions were John Snow, Dean, College of Geosciences, University of Oklahoma, Lisa Bastiaans, Nassau Community College and senior staff of the NWS Training Center (especially Peter Chaston, Richard McNulty, Jerry Griffin, and Thomas Magnuson).

Table 1. Participant Backgrounds.

Doctoral degrees	10
Master degrees	14
Two-year institutions	13
Four-year institutions	11
Public institutions	21
Private institutions	3
Institutional enrollment < 1000	1
1001 - 5000	11
5001 - 10 000	4
> 10 000	7

Table 2. Participant Backgrounds

Geology	4
Geography	7
Anthropology	1
Physics	2
Science Education	6
Earth Science	2
Physical Science	1
Biology/Chemistry	1

Featured guest speakers at the workshop (in order of appearance) and their topics are listed below:

- Warren Washington, AMS President, the American Meteorological Society and the current state of climate studies.
- Roderick Scofield, National Environmental Satellite Data and Information Service, satellite imagery and interpretation.
- Robert Sheets, Director, National Hurricane Center, hurricanes and their coastal hazards.
- Eileen Shea, National Academy of Sciences and NOAA Office of Global Programs, U. S. research programs in global change.
- Joseph Schaefer, Director, NWS Training Center, wind profilers.
- Frederick Ostby, Director, National Severe Storms Forecast Center, thunderstorm-related severe weather.
- Louis Uccellini, Director, Office of Meteorology, NWS, numerical weather prediction.
- Louis Boezi, Deputy Director for Modernization, NWS, the future of the National Weather Service.

In addition to classroom and laboratory work at the Training Center, fieldtrips were taken to the University of Kansas Meteorology Program, hosted by Joe Eagleman, the NWS Topeka (KS) Forecast Office, the National Severe Storms Forecast Center in Kansas City, and the Air Force Global Weather Central at Offutt AFB (NE).

4. RESULTS

A summary evaluation was received from 23 of the workshop participants. The general questions are replies are given in Table 3. All participants felt the workshop was valuable and should be offered to aid other faculty of two- and four-year colleges who teach weather courses such as they.

Table 3. Workshop Summary Results

What is your overall rating of the Faculty Enhancement Workshop in terms of its educational value?

Poor 0 Fair 0 Excellent 23

What long-term effect is Workshop participation likely to have on your:

instruction?

None 0 Some 3 Great Deal 20

use of current weather data?

None 0 Some 2 Great Deal 21

course development?

None 0 Some 7 Great Deal 16

professional interaction with colleagues?

None 0 Some 5 Great Deal 18

How has your perception of the value of the following changed as a result of your Workshop participation?

NWS/NOAA

increased 21 remained the same 2 decreased 0

profession of meteorology

increased 21 remained the same 2 decreased 0

Would you recommend that this Faculty Enhancement Workshop be offered in the future for other faculty?

Yes 23 No 0

Warren Washington, in his discussion of the American Meteorological Society, asked the participants what were five needs they collectively saw in their teaching environments. One evening session was devoted to educational issues based on this question. The participants' perceived needs and the number of times each reply was received are given in Table 4.

Table 4. Undergraduate Needs

1. Better student preparation (HS background), esp. math and science	13
2. Need to upgrade training of in-service faculty , such as this workshop	12
3. More course materials needed (hands-on activities, fieldwork, AV)	9
4. Access to current meteorological data	8
5. Upgrading of support facilities:	
a. More computers available, also software	6
b. Modernization of equipment (replacement)	6
6. Direct and indirect student support	
a. Support for student skills development (math and English)	4
b. More science for pre-service teachers	4
7. Additional faculty preparation and out-reach	
a. Release time for faculty upgrading	3
b. Release time for course development (activities, materials)	3
c. Development and/or dissemination of new teaching methodologies	3
d. Promote in-service opportunities (to work with high schools, esp. equipment)	3
8. General	
a. Enhanced professional communication ("information superhighway")	2
b. More relevant mathematics courses (applied)	2
c. Support (at least partial) for professional activities (workshops, meetings)	2
d. More meteorology/weather courses offered	2
e. Better student motivation	2
9. Others	
a. Better advising of students in major (area of concentration)	1
b. Better staff - administration communication	1
c. Government-education cooperation in materials development and use	1
d. Confront issues of pseudo-science (creationism)	1
e. Enhance stature of educators	1
f. Encourage better students into education	1

The perceived educational needs listing in Table 4 falls into two basic categories, general educational problems and those directed toward the atmospheric sciences. Items 1, 5, 6, and 7 generally suggest the common problems noted in the public media and a number of reports on the science and mathematics performance of American students. The mathematics and science backgrounds should be strengthened, more resources should be found for infrastructure rebuilding, i.e. more computers and replacement equipment. Several items, however, point out areas where the atmospheric sciences have a special interest. The most common response in this category was the expressed need for more training opportunities, such as this workshop, for undergraduate faculty. Participants felt such opportunities are especially needed by faculty members trained in areas other than their teaching assignments and for general renewal. The next most common needs listed were related. They call for (a) "hands-on" instructional resource materials for laboratory and classroom use, and (b) access to current meteorological data in the classroom. Additional comments included enhancing professional communication, offering more weather courses in two- and four-year schools, and catalyzing the use of governmental resources, such as NWS', for educational materials development.

The participants all believed their own teaching will be enhanced and that such updating experiences should be available to others. It was hoped that such workshops will be an on-going process to help a major section of the undergraduate community that does not have a ready forum such as UCAR. A second workshop will be conducted with National Science Foundation support in late July 1995.

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1.6

WEATHER AND LIFE: A COGNITIVE APPRENTICESHIP IN PERSONALIZED MULTIDISCIPLINARY PROBLEM SOLVING

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1. INTRODUCTION

The traditional approach to instruction centers on the teaching of disciplines of study in which students are exposed to a broad background of material which potentially has relevance to their lives. Unfortunately, as has been pointed out by Alexander (1993), students typically go through lower division science courses (which often address the discipline rather than the study involving the discipline itself) with a "get it out of the way" attitude and thus often fail to see the relevance of the topic to their personal or academic lives. This mentality obscures, and even disallows, the fact that all disciplines are related and important.

For these and other reasons, undergraduate education in the sciences has generally been viewed as inefficient and unsuccessful in increasing or improving the student population's scientific literacy (e.g., see Schwartz, 1993 and Magner 1993, 1994). This is a serious problem because those who obtain higher education degrees will be unable to utilize scientific information when they leave college.

In many situations these graduates will make personal and professional decisions based on their comprehension of scientific information (e.g., the interpretation of an environmental impact statement) and may arrive at incorrect conclusions because of their deficiencies in scientific understanding.

Therefore Alexander (1993) has suggested that courses be designed to develop a student's knowledge base through student experiences within a discipline (rather than by the simple transmission method of instruction) in order to meet the needs of the majority of undergraduates and improve scientific literacy. Courses which promote the discovery of knowledge, knowledge integration and communication, and its application (Boyer, 1994) would accomplish this.

2. METEOROLOGY FOR NON-MAJORS

Weather has a broad and familiar appeal because of its commonality of "hands-on" experience in an ever present natural laboratory. From childhood on people are exposed to weather and must respond accordingly. This provides some of the earliest experience in problem finding and problem solving that people have. This active learning environment may therefore be used as a resource to link the experience of science to problem solving and provides an opportunity to correct the people's understanding of weather phenomena that often includes many misconceptions.

These misconceptions limit their ability to properly assess a given situation or to logically identify and render solutions to science-related problems. Therefore, a course entitled "Weather and Life" has been designed to: (1) improve and enhance scientific literacy of undergraduate students, (2) develop knowledge integration skills, (3) develop cooperative problem solving skills, and (4) develop media integration skills, through the study of meteorology.

The course focuses on the interdisciplinary nature and importance of weather in every aspect of life, including social, economic, and industrial consequences. In this way the course can provide a broader, interdisciplinary context of critical thinking and problem solving. The course therefore encourages independent and group learning to foster tolerance and understanding of alternate views and methods. The course also provides important interaction with peers and faculty to develop cooperative problem solving skills.

3. INSTRUCTIONAL DESIGN

To achieve these goals the Weather and Life course consists of topical modules which focus on situational learning. For example, a topical issue such as global warming may be presented as an "answerless problem" which leaves opponents agreeing to disagree. However, the need for a mutual approach in order to progress exists as the consequences of both action and inaction will affect their lives and economies. The complexities of such an approach are reflected by the bias inherent in students' prior knowledge, the availability and reliability of data, and the source of data and constructs.

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Other approaches to situated learning include team teaching--or guest lecturers (e.g., engineering; Collison, 1993), collaborative learning (meteorology; Navarra, et al., 1993), and field courses--or research experiences (e.g., meteorology; Hindman, 1993). Each strives for reality-based learning and is faculty-student intensive. There are also presently several initiatives, including Project ATMOSPHERE (Smith et al., 1994) and Project LEARN (Gellhorn and McLaren, 1994), which focus on the improvement of scientific literacy and education through teacher enhancement.

There are also many other programs and/or educational materials designed specifically for undergraduate students (including research experiences; e.g., see Byrd et al., 1994; Orville and Knight, 1992; Lewis and Maddox, 1991; and Hallett et al., 1990) to foster the development of thinking skills. Many exist for secondary (e.g., Kern et al., 1993; Ruscher et al., 1993; and Snow and Smith, 1990), middle school (e.g., Schmalbeck and Peppler, 1994), and elementary students (e.g., Mogil, 1989) as well.

However, each of these are limited in some way. For example, the team teaching approach directly illustrates interdisciplinary concepts and relevance but is often lacking in hands-on experiences for students. Also, guest lecturers may offer a narrow view of the application of a discipline, may present information outside the context of a student's experience or interest, and assume a similar knowledge and experience base.

In the case of collaborative learning individuals who progress at their own pace may suffer from incomplete knowledge acquisition (because students may not have these skills). Collaboration also focuses on the development of analytic skills rather than scientific knowledge and understanding, and must therefore be directionally biased and limited in the number of viewpoints.

Field courses typically focus on the application of learned course material and may be very narrow in scope when dependent upon a faculty member's research. Although lab experiences do offer an opportunity for critical thinking and problem solving, they often are constrained (and/or narrow in view), often have known outcomes, lie outside the student's realm of understanding, or ultimately require students to learn duties rather than construct new ideas.

Therefore, a combination of these three approaches is necessary for the improvement of scientific literacy, development of knowledge integration and cooperative problem solving skills, and development of a student's critical thinking and media integration skills. This may be accomplished according to the instructional strategies outlined in the oral presentation.

4. WEATHER AND LIFE

The Weather and Life course will consist of a series of modular lectures, labs, independent and group assignments, and discussion sessions. It will emphasize personal and group involvement and the use of multimedia techniques and resources and require oral and written reports by individuals and groups. Through these, students will learn how to access, interpret, and integrate resources in the problem finding and problem solving process and how to relate their findings to different audiences.

The course is the last of a three-part sequence of a science cluster curriculum designed for first and second year undergraduates. Enrollment will be limited to 30 students and it is anticipated that one-half will be education majors, the other half predominantly non-science majors (with one meteorology major).

4.1 *First Week of Class*

At the start of the course, students will be given a pretest to assess their basic meteorological knowledge (of concepts), their analysis and critical thinking ability, and their problem solving and communication abilities. Therefore the pretest will focus on situational problems in which students must determine if weather impacts are possible, what level of significance they might have, and whether impacts may be mitigated and/or prevented. The pretests will be collected and discussed with regard to "correct" answers and related to each students' personal experiences with the weather.

Students will then determine the significance of weather to their lives by identifying five different weather-related impacts each from newspapers, magazines, and professional journals. The increasing level of sophistication will illustrate the significance and interdisciplinary nature of meteorology and improve their scientific awareness. Students will critique the progress and findings of one another in the following class.

In the following (third) class students will select one weather-related topic each from science (e.g., air pollution meteorology), business (e.g., forensic meteorology), and liberal arts (e.g., architecture and design); based on their previous assignment, as a self-determination of the course's content). Potential topics are shown in the oral presentation. Initial discussion will focus on what is known about each topic and students will be asked to prepare a plan of action for discussion in the next class.

In the fourth class students will be assigned to groups in order to access resources relevant to the determination of weather impacts, their significance, and their control. Although it is clear that each topic may fit more than one category, this may not be intuitive to students. Through their cross disciplinary study of the topic, they will find the imposed topical area boundaries to be less important.

4.2 *Weather Study Modules*

Each topic selected will then be studied during a two week period. The first week (Days 1-4) will involve topic investigations and the second week (Days 5-8) knowledge and media integration. At the start of each topic, a quiz will be given to evaluate each students' basic conceptual knowledge. The quizzes will be designed to test their ability to apply knowledge in a limited time environment (similar to business meeting pressure) and to offer quick solutions to new or old problems.

The topic will then be discussed in class (Day 1) by the instructor (or a guest lecturer if appropriate) through a multimedia presentation in which basic information (and conflicting information in some cases) is detailed. Student groups will then be charged with the investigation of various aspects of the information presented.

On Day 2, student groups will assess what is known, or thought to be known, about a topic, or accepted as conventional wisdom. It will then be their responsibility, both individually and to their group, to contact and/or acquire appropriate resources to verify or refute lecture materials and to identify significant problems and associated impacts on Day 3. Upon completion of independent and group research, individuals and groups will report their initial findings on Day 4.

Class discussion will then shift to what should be done about these problems, how they are to be prioritized, and their assignment to individual groups for further research. At this point, the students will become "employees" in the course's "company business" and will act as individuals and "reporting departments" to develop cooperative problem solving skills. The task of each employee and department will be to offer solutions for the aspects of the weather related problem assigned to them on Day 4.

Through consultation with group leaders and the instructor on Day 5, students will need to define specific tasks toward achieving a solution to their specific problem and understand its relationship to the whole. Active use of resources, continual revision of their work plan, and consultation with peers will be necessary to complete their jobs during Day 6 and oral and written reports on Day 7.

Peer review, evaluation, and discussion of oral reports on Day 8 will determine the clarity, usefulness, relevance, and completeness of student and group research. Written reports will be evaluated by their instructor and by the students with regard to each student's performance in the "company's business" and allow for an interdisciplinary assessment of each student's writing ability. Follow up tasks may be suggested to each group and individual to obtain further information, check information obtained, and/or rework a presentation.

Further discussion will focus on determining the "company's" accepted policy and planned action on the weather related problem. This will require negotiation and compromise by the "employees" of the different "departments". Students will then better appreciate the need to consider various solutions to problems and understand how those solutions were derived and must "stake their job" (and thus their grade) on what they report. They must be sure that they have acquired accurate scientific information and clearly understand that information and its proper application.

5. DISSEMINATION

A CD-ROM resource disc based on the Weather and Life course is planned. The multimedia disc will contain maps of weather patterns, reports of weather studies, tables and charts of climate data, video clips of weather phenomena, and satellite and radar imagery. The disc interface will be designed to allow guided browsing and searching and will have regional instructional materials and various instructional plans so that teachers may select exercises, information, and answers for their particular geographic region and according to their needs.

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1.7 NEW METEOROLOGY PROGRAM AT THE U.S. AIR FORCE ACADEMY INTEGRATES COMET MULTIMEDIA AND COMPUTER WEATHER LAB INTO UNDERGRADUATE CURRICULUM

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1. INTRODUCTION

The United States Air Force Academy has developed an undergraduate meteorology program within the Department of Economics and Geography and the Department of Physics. Meteorology cadets will enter the Meteorology Track within the Geography Major, and will complete at least 24 semester hours of undergraduate atmospheric science courses before graduating. The program meets or exceeds both the World Meteorological Organization and National Weather Service academic standards for undergraduate atmospheric science curricula. The Class of 1995 will be the first to graduate cadets in the Meteorology Track. Many graduates of the program will become weather officers, directly supporting the missions of the U.S. Air Force and Army. Other graduates may become pilots or navigators, or choose other career fields that would benefit from an intimate knowledge of the atmosphere in which they perform their mission. The Academy's facilities for the meteorology program include a well-equipped, modern, computer-based Meteorology Laboratory and a Multimedia Classroom (see Knipp and Heckman in this preprint volume). The Meteorology Lab houses 12 Automated Weather Distribution System (AWDS) workstations, a WSR-88D Doppler radar Principle User Processor (PUP), a PC-based satellite looper with dedicated access to GOES, METEOSAT and GMS satellite images, and a computer-based learning (CBL) delivery system for incorporating multimedia modules into classroom discussions. Seven additional CBL systems reside in the Multimedia Classroom, and can be used for group or individualized learning sessions. Two additional AWDS workstations are located near faculty offices for developing classroom materials, and CBL systems are placed in other locations, including the Cadet Library for access by students during the evening and on weekends. Most of the equipment was donated to the Academy by the Air Weather Service.

2. THE METEOROLOGY TRACK CURRICULUM

Upon graduation, a cadet in the meteorology track will have completed the eight meteorology courses (Table 1), totaling 24 semester hours. These courses are in addition to a rigorous core sequence of 31 courses in the basic sciences, humanities, social sciences and engineering, five courses required for the Geography Major, including a computer-assisted map analysis and a remote sensing course, two additional mathematics courses beyond the core, and three military arts and sciences courses. A cadet has only one open option, which often is a flight training course. Military and athletic duties also make serious demands on a cadet's time.

TABLE 1

Course Name	Course Description
Geography 320	Climatology
Physics 320	Introduction to Atmospheric Science
Physics 330	Atmospheric Physics
Physics 430	Atmospheric Dynamics
Physics 431	Atmospheric Circulation and Energetics
Geography 451	Synoptic Meteorology
Geography 452	Mesoscale Meteorology
Geography 460	Satellite Meteorology and Image Interpretation

3. FACILITIES

Providing a solid academic foundation in atmospheric science is the primary purpose of the meteorology program. In addition, the facilities feature operational equipment in current use in base weather stations, allowing cadets to become familiar with the wide range of products and equipment they will use after graduation.

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3.1 *The Meteorology Laboratory*

Several meteorological data acquisition and display systems reside in the Meteorology Laboratory. Ten of the twelve AWDS workstations in the lab are situated in the classroom area. The remaining two workstations are placed in a separate area, partitioned from the classroom, to allow walk-in users to gain access to the AWDS information with a minimum of distraction to an ongoing class. The satellite looper features two monitors, one that normally displays current images, While the other can be used to view past weather events. The current images are also fed into the Academy network on a dedicated video channel for display in other classrooms, or in the cadet dormitories.

A sophisticated switching and display system has been designed to integrate the various video displays for AWDS, the satellite looper, the WSR-88D PUP, the multimedia CBL system, a VCR, and a visual presenter into a switching system that could display up to three video signals simultaneously in the classroom. A three-gun color projector can display one image on a projection screen at the front of the room, while two large screen color monitor pairs placed on the sides of the classroom can each display a different video source. The instructor can control the entire video and audio display system via a hand held remote control. Considerable effort will be expended in designing the curriculum and in altering teaching techniques to capitalize on this integrated video display capability.

3.2 *The Multimedia Classroom*

The Air Force Academy has been involved with computer-aided learning for many years. In recent years, the Academy has had a role in the development of several of the COMET modules, used both as a means of providing continuing education for field forecasters, and recently as a learning tool in the university environment. The Multimedia Classroom houses seven CBL computer workstations in an arrangement conducive to both individual learning, or in group or instructor-led situations. A complete set of the current COMET modules is available at each workstation. A portion of our current effort in course development is devoted to effectively incorporating these CBL resources into an undergraduate atmospheric science curriculum.

4. SUMMARY

The new Meteorology Track in the Geography Major at the U.S. Air Force Academy will provide an academic opportunity to future Air Force officers to become familiar to the medium in which the Air Force operates. An exceptional investment in terms of facilities and human resources has been made available for meteorology instruction at the Academy. We hope to make our program an innovator in incorporating multiple computer-based data sources and computer-based learning in an undergraduate environment.

1.8

INTEGRATION OF INTERACTIVE MULTIMEDIA INTO THE METEOROLOGY CURRICULUM AT THE UNITED STATES AIR FORCE ACADEMY

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1. INTRODUCTION

A new meteorology track was recently formed in the Department of Economics and Geography which is jointly staffed and operated with the Department of Physics (see Koehler, et al., in this preprint volume). In addition to having an array of modern analysis and observing tools in the meteorology laboratory, cadets and faculty will have a unique opportunity to use state-of-the-art interactive multimedia (IMM).

Heckman and Graziano (1993) outlined the basic ideas of integrating IMM into the new curriculum. This paper expands upon these initial ideas by describing the rationale for using IMM, describing the implementation plan, showing how IMM has been used in the initial stages of implementation, and outlining potential revisions.

2. WHAT ARE THE PEDAGOGICAL ADVANTAGES IN USING INTERACTIVE MULTIMEDIA?

According to Chung and Reigeluth (1992), instructional outcomes fall into three categories: effectiveness, efficiency, and the appeal of the instruction to the learners--our goal is to show that the learning model used in the meteorology track improves these outcomes by integrating IMM. Simply integrating IMM into the curriculum is not sufficient as pointed out by Reeves (1993). He strongly suggests that IMM, to be effective, must be designed around a solid pedagogy. Our approach rests on two fundamental underpinnings. First, the US Air Force Academy (USAFA) actively promotes instruction that is grounded in solid pedagogy. Second, IMM programs used at the *Cooperative Program for Operational Meteorology, Education and Training's* (COMET®) which we are integrating into the new curriculum, are designed to combine solid pedagogy with sound science (see for example, Wilson, et al., 1991 and Lamos, et al., 1993).

Are there ways that the traditional "lecture-laboratory-research" learning model used in the atmospheric sciences can be improved by embracing the notions of cognitive science and applying educational technology? We think the answer is yes! Reeves (1993) suggests that in order for students to realize the potential of IMM, it must be designed around three basic tenets of contemporary cognitive theory as outlined by Resnick (1989). IMM should be designed so that: 1) learning is accomplished through "knowledge building"; 2) learning is improved through the situation that it is presented to the learner; and 3) learning is "knowledge-dependent." It is not the purpose of this paper to dwell on the details of cognitive science, but rather to show that improvements in the learning model rest not solely on better science, faculty, or the use of IMM, but also on the combination of these elements with modern learning concepts and applications.

3. IMPLEMENTATION PLAN

Our implementation plan will extend over several years, starting from a rather simple approach and will be revised based on assessments at each phase. The following sections describe our initial phase of implementation.

3.1 *How are instructors and students using multimedia?*

Initially, multimedia courseware will be integrated into the curriculum using three techniques: individual, self-paced learning; cooperative learning between two or

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+Serves as adjunct instructor as part of Air Weather Service reserve assignment three cadets; and small-group, instructor-led sessions. Each of these strategies has certain advantages and disadvantages. Table 1 describes the use and advantages of each strategy.

Table 1. Implementation strategies, uses, and respective advantages of IMM.

Implementation Strategy	Use	Advantages
Individual learning	-all or portions of lesson (s) completed by student -homework assignments -laboratory exercises -instructor used as mentor	-self-paced, high learner control -time for reflection and review, as needed -highly flexible -fully utilizes the design of some programs
Cooperative learning	-all of above but work is accomplished in small groups rather than individually	-self-paced, high learner control -maximizes student interaction -increases efficiency of learning -creates team building
Small group classes	-can take place of lecture -used in combination with lecture	-integrates instructor with multimedia -maximizes social contact among students and instructor

3.2 *What hardware/software configurations will be used?*

Students and faculty will have the opportunity to employ IMM in several ways: small group/class discussion, instructor mentoring, and individual study. The generous donation by Air Weather Service of 10 COMET delivery systems (COMET, 1994) to the meteorology program has allowed faculty to be directly involved in designing the IMM work areas for optimal use. IMM inherently affords the opportunity for a high degree of learner control and offers the possibility of simultaneous, multiple uses. We are designing the Multimedia Classroom (MC) with seven of the workstations to take advantage of this flexibility by allowing cadets to work in small groups or individually as part of a class or homework assignment. Further, an instructor may wish to hold class in the MC where students can work on an IMM lesson, while the instructor provides guidance or gives a short lecture. For greater flexibility and to allow for more individual student use, three systems have been deployed outside the MC. One is located in the Physics Department, another is in the Academy library where cadets may use it during weekends and non-duty hours, and the third is in the Meteorological Laboratory for use in lab sessions or lecture.

3.3 *What are the sources of IMM courseware?*

In the early stages of evaluation, two sources of multimedia courseware are being used. The first is COMETs *Forecaster's Multimedia Library*. COMET is developing an extensive curriculum specifically designed for operational forecasters. This curriculum is organized around four basic tracks: Basic Topics, Aviation Meteorology, Convection, Extratropical Cyclones, and Special Topics. In the latter track, topics such as marine, tropical, and polar meteorology are treated. In addition, NOAA is funding the production of unique modules covering a wide range of topics including GOES-I, Fire Weather and Agricultural Meteorology, QPF Forecasting, and others.

In addition, other programs will be used. For example, the Australian Bureau of Meteorology has developed a cloud identification program. The introductory course also uses computer spreadsheets and math applications software that allows students to translate data and equations into useful graphics and illustrations. As other IMM becomes available, it will be evaluated and integrated as appropriate.

3.4 *How is multimedia courseware being used and how will it be assessed?*

Initially, we had two graduate school cadets work through two COMET modules as part of an independent study course. Starting in the fall 1994 semester, we focused on integrating IMM in the ways described above and developing an assessment plan. Table 2 summarizes the ways IMM has been integrated into the curriculum.

In the fall 1994 semester, *Physics 320: Introduction to Atmospheric and Space Science* was revised based on the results of using IMM the previous semester. Several modules from the COMET library and the Australian Bureau of Meteorology (BMTC) cloud identification program were used throughout the course with a variety of strategies. Table 3 details how these programs were used.

Table 2. Partial list of IMM used in Physics 320, Fall 1994

Lesson/project	IMM material used	Instructional strategy used
Condensation	-BMTC *Cloud Identification*	-homework/self study
Stability and cloud development	-several tutorials from COMET modules: *Heavy Precipitation and Flash Flooding (HPFF)* and *Boundary Detection and Convection Initiation (CI)*	-small group study with instructor mentoring
Condensation	BMTC *Cloud Identification*	-small group discussion -homework assignment
Stability and cloud development	-several segments from HPFF -interactive exercises on clouds and Skew T-log p diagram in CI	-small group discussions
Mid-latitude cyclones	-selected tutorials from COMET *Extratropical Cyclones I*	-small group discussions
Special project	-complete a grouping of COMET modules of choice -complete a summary and report to class the set of key concepts and applications	-individual study

In the same semester, *Geography 451: Synoptic Meteorology* was taught for the first time. IMM was integrated into several sections of the course. The same basic approach was followed in terms of instructional strategies, except that different IMM programs were used. For example, COMET's *Forecast Process, Numerical Weather Prediction,* and *Extratropical Cyclones I* were used extensively.

During the semester, a number of assessment instruments will be conducted as part of our on-going evaluation. Results will help develop revision to courses and plot our future plans.

4. WHAT ARE THE FUTURE PLANS?

Future plans center on two main areas: further revisions to the Multimedia Classroom and integration of other IMM programs. In its current configuration, the MC consists of seven stand-alone workstations placed on individual tables. Potential modifications to this initial phase may include networking the workstations. In addition, we may configure some of the workstations into one or more pod-arrangements similar to the Foreign Language Department's Multimedia Laboratory.

The other potential area of development may be the addition of IMM programs designed specifically for academic instruction. It can be difficult to integrate IMM programs that were designed for other purposes, such as the COMET modules which were designed for operational forecasters to be used at forecast offices for individual learning (Heckman, 1994). The USAFA has the distinct advantage of having resources available to produce custom IMM through the Department of Education and other resources, but a much more careful evaluation will have to be conducted before this is considered.

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1.9

A SURVEY OF THE USE OF COMET's® *FORECASTER'S MULTIMEDIA LIBRARY* IN THE ACADEMIC COMMUNITY

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1. INTRODUCTION

The use of interactive multimedia (IMM) is becoming an integral part of the education and training program for the nation's three federal forecasting services, the National Weather Service, the Air Weather Service, and the Naval Meteorology and Oceanographic Command. Although COMET's primary mission is to support these three agencies in their continuing education needs, IMM has a place in the academic community as well.

COMET has collaborated with the university community in assessing the feasibility of using IMM in instruction. In 1992, COMET and Weather Information Technologies, Inc. (WITI) conducted an evaluation of COMET modules at five universities in the USA and Canada. The responses suggest that both instructors and students believe that IMM has a place in the spectrum of instructional methodologies at the university. Following a lively discussion on the role of new educational technologies at the Unidata/NSF sponsored Mesoscale Meteorology Workshop in June 1994, the author thought it might be of interest to the community at large to see how instructors and students are using IMM in instruction.

A survey was sent to 15 universities that purchased an IMM workstation and at least some of COMET's *Forecaster's Multimedia Library*. An analysis of the 13 returned surveys follows.

2. RESULTS

Table 1 describes the universities that responded to the survey, the types of IMM being used, and the COMET modules in use. Table 2 outlines the number of students using IMM and details about the computer systems and hours of use. Table 3 details the use of the COMET modules in the curriculum, in terms of which module is being used in specific courses and by what instructional method. It also links this use to the institutions listed in Table 1. For example, one can see from Table 3 that portions of several modules are being used in a mesoscale course titled "Mesoscale Analysis and Forecasting" developed by the institution with the number "6" which corresponds to the Pennsylvania State University in Table 1.

Tables 4 and 5 describe advantages (Table 4) and disadvantages (Table 5) in using interactive multimedia in the curriculum. From the responses, the author identified a set of categories and tallied the total number of responses per category which are listed in Tables 4 and 5 in decreasing frequency. For example, the observation that IMM allows for a "self-paced learning environment" ranked first (10 answers were grouped into this category) among 10 categories. On the other hand, there were categories that nearly tied for the most important disadvantage: "too costly" scored 6 while "difficult to integrate into the existing curriculum" tallied 5.

Some of the categories appear to be closely related which might lead one to different conclusions about the uses of IMM. For example, in Table 4, one could conclude that "good case studies/good examples of modern data sets" and "effective display of data and information" are the same. However, in analyzing the data, it appeared that the answers given were in two distinct categories. Into the latter category went answers like, "visual improvements to the blackboard" and "effective method of displaying information," while responses like "good examples of data from modern observing systems," and "easier to create exercises than by going from scratch" went into the case study category. There is always some ambiguity when the respondent does not select from predetermined categories, but the author hopes that his interpretations reflect the respondents' intent.

The final question focused on how instructors thought that the COMET modules could be made more effective in an academic environment. Although the modules are designed specifically for use at forecast offices by operational forecasters, some modifications are possible. These suggested modifications are listed in Table 6.

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Table 1. General information about institutions surveyed. COMET module titles in use are as follows: *Workshop on Doppler Radar Interpretation*=WDR; *Boundary Detection and Convection Initiation*=CI; *Heavy Precipitation & Flash Flooding*=HPFF; *Forecast Process*=FP; *Numerical Weather Prediction*=NWP; and *Extratropical Cyclones Volume 1*=ET1.

Institution	Source of IMM	COMET module titles in use
(1) Lyndon State College	COMET	WDR, FP, CI, HPFF
(2) McGill University	COMET	WDR
(3) Mississippi State University	COMET	WDR
(4) University of Wisconsin	COMET, Other, Custom	WDR, NWP, FP, CI, HPFF
(5) University of Missouri	COMET	
(6) The Pennsylvania State Univ.	COMET	WDR, CI, HFPP, FP
(7) United States Naval Academy	COMET	WDR, CI
(8) University of Oklahoma	COMET	WDR, CI, FP
(9) State University of New York, Brockport	COMET	WDR, HPFF, CI
(10) Colorado State University	COMET	HPFF, FP
(11) Millersville University	COMET, Other	CI, FP
(12) US Air Force Academy	COMET, Other	WDR, CI, HPFF, FP, NWP, ET1
(13) Iowa State University	COMET, Custom	WDR, CI, FP

Table 2. Information about computer systems and use.

	Total number of IMM workstations available			Total number of students per semester working on multmedia				Hours of operation for the multimedia workstation (s)		
	1	1-3	>3	1-5	6-10	11-15	>15	0800-1700	0700-2200	24h
# Institutions	13	0	1	2	1	5	3	3	4	3

Table 3. Methods of use of COMET multimedia titles in courses offered. Number following course corresponds to the university listed in Table 1(number to the left of the institution's name). Segment use as follows: A=entire module used in course; B=specific segments used as lecture or self-study; C=used in laboratory; or D=used as special project (s).

Course		Multimedia Title	A	B	C	D
Synoptic Meteorology						
Synop Lab	(13)	CI	X			
Synop Lab	(8)	WDR, CI		X		
Introduction to Synop						
Synop Lab (soph)	(8)	FP		X		
Synop Course	(7)	To be determined				
Synop Course	(12)	FP, ET1, NWP		X		
Senior Synop Lab	(13)	CI, WDR	X	X	X	
Mesoscale Meteorology						
Mesoscale Modeling	(10)	NWP		X		
Mesoscale Met	(8)	WDR, CI		X		
Mesoscale Dynamics	(9)	HPFF	X			
Mesoscale Analysis & Forecasting	(6)	WDR, CI, HPFF		X		
Weather Laboratory Series	(10)	FP, HPFF	X		X	
Satellite & Radar Meteorology						
Satellite Met Course	(11)	CI, FP		X		X
Special Projects						
Undergrad Indep Study	(6)	WDR, CI, HPFF, FP.	X			
Independent Study	(7)	NWP				
Independent Study	(9)	To be determined	X			
Independent Study	(12)	WDR, CI WDR, CI, FP		X		
Cloud Physics						
Other Courses						
Intro Atm & Space Sci	(12)	WDR, CI, HPFF, ET1		X		X
Intro to Met (non-deg)	(13)	Limited use		X		

Table 4. Advantages in using interactive multimedia in instruction. When possible, the five most important advantages were organized into categories. Number of responses are shown to the right of each category or response.

Category	Number of responses
Self-paced learning environment	10
Learning strategies create effective (interest, enthusiasm) learning	7
Good case studies/good examples of modern data sets	5
Effective display of data and other information	4
Students exposed to other experts	3
Students change from passive to active learners	3
Topics address needs for mesoscale meteorology	3
Retention is higher	2
Emphasis on operational meteorology	1
Use in cooperative learning environment	1

Table 5. Disadvantages in using interactive multimedia in instruction. When possible, the five most important disadvantages were organized into categories. Number of responses are shown to the right of each category or response.

Category	Number of responses
Too costly: need more workstations; requirement for support staff	6
Difficult to use in classroom	5
Too time consuming: instructor review; modules too long; or instructor knowing system	4
Difficult to convert students or faculty to multimedia concept	2
Difficult to integrate into existing curriculum	2
Too slanted to operational meteorology	1
Software/hardware problems	1
No interaction with instructor if learner has questions	1
Colors washed out/poor resolution of imagery	1
Lack of evaluation	1
Negative incentive for instructors to improve learning program	1
Lack of application to minority students	1

Table 6. Suggested modifications to the COMET modules.

Recommended changes to COMET courseware	Number of responses
Expand the scope of modules	
Provide an index for the content of the modules	2
Provide more advanced material	
Do not change	
Provide additional case studies	
Provide for cross platform use, e.g., Mac, PC, Unix	

5. ACKNOWLEDGEMENTS

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1.10 SYMBOLIC MANIPULATORS IN THE CLASSROOM: USING STUDENT RESEARCH TOPICS IN OCEANOGRAPHY AND METEOROLOGY TO ENHANCE TEACHING/LEARNING OF ADVANCED MATHEMATICS

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1. BACKGROUND

The curriculum at the United States Naval Academy traditionally has had a strong science and engineering emphasis. For example, all students regardless of their major take chemistry, physics, differential and integral calculus through differential equations, and a variety of engineering courses. The purpose of such a rigorous program in science, mathematics, and engineering is to provide all graduates with an adequate background to pursue any of the advanced technical programs in the Navy or Marine Corps.

One of the majors available at the Naval Academy is Oceanography, which focuses on physical oceanography, meteorology and air-sea interaction - areas clearly important for the operational environment that future naval and marine officers will encounter (Smith and Gunderson, 1994).

For the past several years the Oceanography and the Mathematics Departments at the U. S. Naval Academy have collaborated and redesigned the sophomore/junior level mathematics core courses. During this process a new mathematics curriculum has been developed thatt shows a better balance between science and applied mathematics that serves the needs of the students majoring in oceanography more effectively in their preparation for advanced courses, and in their future endeavors as naval officers.

This curriculum differs in three ways from a traditional one based on the classical treatment of advanced science and engineering mathematics. First, the entire curriculum is based on the new technology of computer algebra systems where a symbolic manipulator such as *Mathematica* is used in every aspect of the instruction and problem solving. Second, there is no clear demarcation as to when a mathematical concept begins and ends and when an oceanographic concept is being introduced (i.e., there is a continuity to the mathematical and scientific concepts rather than spending weeks or months studying differential equations and their properties in isolation and then applying them to fluid flow problems. In the new curriculum the mathematical tools and oceanographic concepts are introduced in their natural setting when needed. Third, each student is given a substantial project due at a special juncture during the year where, in close collaboration with the instructor, a basic mathematical model of an oceanographic concept is pursued well beyond the usual offerings of a classroom setting. One of the side benefits of these projects is a writing assignment that goes with each project, thereby reinforcing the notion that it is important to be able to communicate one's knowledge of mathematical and scientific concepts to others.

2. ROLE OF *MATHEMATICA*

The symbolic manipulatorr *Mathematica* is available on two computer networks at the Naval Academy. All students enrolled in a mathematics course related to this curriculum have automatic access to these networks. At the beginning of each semester daily computer assignments on *Mathematica* reinforcee some of the basic concepts from elementary calculus, while some

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rudimentary tools from the UNIX operating system and network file management are introduced.

This software, with its remarkable facility with graphics, symbolic treatment of vector calculus operations, and its numerical capability in solving differential equations and root finding, is a natural tool for the level of mathematical modeling attempted in this curriculum. The goal in using a software package on a computer network is to give the students a tool that, much like a hand calculator, is available to them throughout their educational career at the Naval Academy and not just during a short respite when they take a required course.

3. USE OF PROJECTS TO REINFORCE LEARNING

The mathematical concepts that are covered in the current curriculum parallel what was presented in the old one. The students still receive a heavy dose of instruction in methods for solving ordinary and partial differential equations. However, a student also receives concurrently a thorough discussion of the origin of these systems of differential equations. To achieve that, a complete treatment of vector calculus in conjunction with the kinematics of fluid motion are presented. The terminology of vorticity, stream and potential functions, and flux are part of the everyday language and numerous examples ranging from the flow past the cylinder to Stommel's steady-state model for the Gulf stream are discussed at various parts of the curriculum. It was at this stage of the development of the curriculum that a strong collaboration occurred between the Mathematics and Oceanography departments to reach agreement on a set of common terminology and the fundamental concepts of oceanography that students must see prior to taking more advanced courses.

Three of the long-term projects developed as student/instructor collaboratives are presented in poster format at this conference. They are:

* Stommel's model for wind driven circulation (Strong and Gunderson, 1995),

* Austin and Fleischer's treatment of the cumulus entrainment problem (Preyer and Smith, 1995), and

* Burgers' equation and breaking of waves (Garrett and Malek-Madani, 1995).

All of these projects have a strong element of *Mathematica* in them; without its presence it would be rather doubtful that such projects could be attempted at this point in the educational process of a student. It should be emphasized that any other software package with the basic capabilities of *Mathematica* (e.g., *Maple* or the Math Symbolic TOOLBOX of *Mathlab*) could readily replace thispackage. Other projects developed for this curriculum include:

* The Rayleigh-Benard flow and chaotic advection, motivated by the paper of Camassa and Wiggins (1991),

* Fluid flows past a cylinder and in a bay,

* Exact eddy solutions of the Navier-Stokes equations, motivated by the paper of Welsh (1981),

* A *Mathematica* experiment on Kelvin's theorem and vorticity,

among others.

All of the above projects and a comprehensive set of notes that have been developed for this curriculum are available. (For information on how to access these materials, please request via email from the corresponding author at rmm@sma.usna.navy.mil.)

4. CONCLUSION

It is fair to say that a project of this magnitude would not have reached fruition without a close collaboration between the two participant departments. Early in this process the Mathematics and Oceanography departments communicated

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to each other their needs, their capabilities and their limitations. After a series of trial and errors, this project has reached a stable stage and has achieved success in convincing the midshipmen that mathematics is indeed a useful tool in understanding the complex nature around them. Perhaps the single most important contribution of this approach in the curriculum is the creation of long-term projects. It is expected that through such projects that interdepartment collaboration will continue for years to come.

ACKNOWLEDGEMENT

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1.11

CLASSROOM APPLICATIONS OF INTERACTIVE METEOROLOGICAL VISUALIZATION

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1. LEAP— Laboratory for Exploration of Atmospheric Processes

Through support of the National Science Foundation's Division of Undergraduate Education, the Department of Meteorology at Texas A&M University was able to establish a UNIX-based computer laboratory to aid in undergraduate and graduate education. The main objective was to allow for complete investigation of the spatial and temporal relationships between meteorological variables in atmospheric circulations. For this, it was felt that three-dimensional visualization would be needed. After careful consideration, fifteen Silicon Graphics (SGIs) Indy-PCs and one Indigo2 with XZ graphics was purchased.

Each of the Indy PCs were equipped with 48 MB of RAM, a 16-inch (1280 X 1024 pixel resolution) color monitor, and a 535 MB internal disk drive. The Indigo2, which acts as a server to the other machines, was equipped with 96MB of RAM, a 19 inch (1280 X 1024 pixel resolution) color monitor, Galileo video board, and a 2.3 GB external disk drive.

Initial experience with the computer laboratory indicated that the Indigo2 was an extremely capable machine. The Indy PCs, on the other hand, were terribly slow at 3-D visualization. Delays between 4-9 seconds after a user's interactive command and the machine's response were typical. While this may have been good enough for research applications, it severely limited the pace at which a coordinated laboratory exercise could be conducted.

Fortunately, soon after the equipment was shipped to Texas A&M, SGI announced an upgrade for the Indy PCs. With support from Texas A&M, the department upgraded the Indy-PCs to Indy-SCs and has also added a 9 GB external disk drive and an 8mm ExaByte tape drive for I/O and backups. These upgrades helped the LEAP to a more desirable teaching environment.

This report will describe how the LEAP is used in undergraduate and graduate meteorological education. While three-dimensional visualization is an important tool, other forms of meteorological displays will also be described.

2. Tools for Education

LEAP serves the full range of undergraduate and graduate students. Freshman meteorology majors are exposed to weather information using LEAP in a new course, Weather Forecasting, taught by Nielsen-Gammon. Sophomores, both majors and non-majors, use LEAP to examine atmospheric circulations in a honors section of an introductory meteorology course. Juniors, seniors, and graduate students use LEAP in a variety of observational meteorology courses taught at those levels.

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LEAP also served as the basis for a week-long course in Weather for junior high school students under the Supporters of Excellence in Education Program. The mini-course was taught by Michael Nelson, a graduate student at Texas A&M University.

In all these courses, the goal is the same: to use computer-based methods to examine and explore atmospheric structure and motions to gain a better understanding of the characteristics and physical properties of meteorological phenomena. Several software packages are available as tools to achieve this goal.

The most commonly used tool is MOSAIC, developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois Urbana—Champagne. MOSAIC uses Open Software Foundation's MOTIF as its interface and can be run on a wide variety of computer platforms. Through MOSAIC, the students have access to the World Wide Web which contains text and graphical products available from several university and government laboratories. Satellite images, current weather maps, and area-specific forecasts are examples of the type of meteorological products available on the Web via MOSAIC.

Daily time series of temperature, humidity, pressure, winds, rain, and solar radiation taken from automated weather stations deployed in central Texas are available on the Meteorology Department's own Web server. These data are used to illustrate simple concepts of the diurnal cycle, time lag between peak solar radiation and maximum temperature, and the relationships between physical quantities. Structures of atmospheric circulations, such as cold fronts and thunderstorm outflows, are also examined using time series data.

To gain more insight to the physical relationships between atmospheric motions and the weather, it is desirable to display data from several sources in the same geographic space. Zeb, a software package developed by the Research Data Program at the National Center for Atmospheric Research (NCAR), can simultaneously display information from surface, upper-air, radar, satellite, and lightning detection sites. Modifications to this software allow near real-time ingestion of Doppler radar data from the Texas A&M University's Doppler radar, the National Weather Service Doppler radar, satellite data feeds, the National Lightning Detection Network, and Texas A&M's automated weather stations. Zeb allows information about rain, clouds, lightning, and surface conditions to be overlaid to quickly illustrate the structure of weather systems. Loops of the images can be constructed to explore the evolution of the atmospheric motions. Special Zeb data sets from field programs in the tropics and midlatitudes are also available from NCAR. Laboratory exercises based on these data are under development at Texas A&M University.

GEMPAK is another tool used to display meteorological data in a common framework. Originally developed at the Goddard Laboratory of the National Aeronautic and Space Administration (NASA) and now under continued development at the National Meteorological Center (NMC), with additional functionality contributed by Unidata (a program of the University Corporation for Atmospheric Research), GEMPAK is designed to display and analyze data from surface sites, rawinsondes, gridded numerical output, satellite imagery, and lightning locators. One of the strengths of this tool is the ability to display and perform standard analysis of meteorological fields, particularly from numerical model output. With GEMPAK it is possible to display and loop numerical forecast products obtained from NMC. Hence, the development of a large-scale cyclone and associated fronts can be viewed from the initial perturbation to the fully developed mature cyclone. Large-scale three-dimensional motions can also be easily explored from the initial model data assimilation.

GEMPAK and Zeb are complimentary in the sense that GEMPAK extends the access to meteorological information beyond that obtained through our own local data network and displayed in Zeb.

For more elaborate three dimensional visualization, Vis-5D (under development at the Space Science and Engineering Center at the University of Wisconsin, Madison) displays three-dimensional gridded data using isosurfaces, two-dimensional slices, trajectories, and looping. Four dimensional wind fields in convective storms and output from convective cloud models have been fully explored using Vis-5D. Within Vis-5D it is possible to create isosurfaces of vertical motions and horizontal winds to illustrate the concept of mass continuity and acceleration. More advanced classes use the tool to explore the dynamics of atmospheric circulations. For example, the radar reflectivity and vertical motions can be displayed with rear-to-front horizontal flow to explore the interactions between large and small scale circulations within convective clouds. Instead of relying on tedious mathematical equations, the students are able to see for themselves the response of the atmosphere to dynamical forcing.

Together, MOSAIC, Zeb, GEMPAK, and Vis-5D provide exceptional capability to aid in the development of computer-based laboratory exercises. Each software package offers a wide ranging set of commands which control virtually every aspect of the display on the computer screen. The manner in which these tools are used depends greatly on the level of the course in question.

3. Teaching Methods

Most of the lower-division laboratory exercises have been prepared well in advance of the class and care has been taken to make the software tools discussed above transparent to the students. The intention is to spend time discussing the meteorology of the displayed information and not how the images are generated. One of the greatest challenges for the instructor is to move the students rapidly beyond the "gee-whiz" aspects of color-enhanced data visualization and into using the computer as a tool for examining the physical concepts being discussed.

In general, laboratory exercises for lower division courses are taught in a coordinated fashion. An instructor gives commands for the students to enter at the terminals. Making sure that all 15 workstations are at the same point, the instructor describes the displayed image and discusses the points that need to be emphasized. The instructor also asks questions based on the objectives for that exercise as the lab proceeds. Students are actively encouraged to interact during the lab.

The freshman-level Weather Forecasting course is taught using a seminar-topic format. Topics for discussion are motivated by a desire to understand how weather evolves. Hence, the course relies heavily on rapid access to real-time meteorological data and forecasts. Students are given ample opportunity to explore the current weather observations and to ask questions concerning atmospheric processes. The class session ends with students making their own forecast and entering it into the computer system.

After the laboratory period is over, the students are allowed to continue exploring the available data at their own pace. Frequently, however, the complexity of the Zeb and GEMPAK software discourages independent learning. While MOSAIC has an easy to use point-and-click interface, the student is limited to the set of images that were generated prior to the material being placed into the MOSAIC database. The three-dimensional data are generally unavailable for further analysis.

Vis-5D also has a simple interface and has the advantage of using the entire three-dimensional database to generate its images in real-time execution. After a relatively short introduction to Vis-5D, we have found that most students quickly become comfortable trying out the various options and features of the software. Laboratory exercises that can use this software tool lend themselves to independent exploration more readily than those exercises based on Zeb or GEMPAK.

Upper-division and graduate laboratory courses often start with a similar teaching method as the lower-division courses. Much of the lab is coordinated with an instructor interpreting the displayed information. With time, the students are expected to gain familiarity with the available software tools so the instructor can pose questions and have the students decide how to analyze the data to answer the question. This effort involves short training exercises to illustrate the software capabilities. Abbreviated user manuals are also distributed so the students can develop some expertise with the software at their own pace. At all times, an instructor is available during the scheduled class period to assist the students.

Graduate students use LEAP to access and analyze data sets for independent study courses and to complete self-paced class projects. For these applications, the instructor provides very little assistance to the individual student. Indeed, several students have developed their own software tools to perform special data analysis.

4. Availability of Laboratory Exercises

Several exercises have been developed using the MOSAIC interface available through the World Wide Web. Anyone connecting to the Texas A&M Department's Web server can access and use the laboratory exercises that are maintained under the teaching section of the home page. With time, several new laboratory exercises will be developed and made available. Comments, suggestions, and questions can be sent to the corresponding author.

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P1.1 USING *MATHEMATICA* TO ENHANCE LEARNING OF ATMOSPHERIC PROCESSES: ENTRAINMENT INTO CUMULUS CLOUDS

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1. INTRODUCTION

Topics in the atmospheric sciences offer excellent real-world examples of physical phenomena that demonstrate the application of advanced mathematical concepts. Since the differential equations governing the behavior of many atmospheric phenomena are quite complex, utilization of mathematical software packages, such as *Mathematica*, can be valuable tools to enhance the understanding of such mathematical concepts. Application of the software package provides a technique to solve the differential equations and graphically display the solutions for the mathematical representation of the physical phenomenon under investigation.

This paper reconsiders a classical model of entrainment of cumulus clouds described in the works of Stommel (1947) and Austin & Fleischer (1948). The entire derivation of the governing equations of this model is based on the first principles of thermodynamics. The solutions to these equations for various physically significant parameter ranges are carried out and results presented on the symbolic manipulator *Mathematica*. In addition, pedagogical aspects of the mathematical and physical treatment of the entrainment process are discussed.

2. PURPOSE

The purpose of this project was to utilize the *Mathematica* software package as a tool to model entrainment of cumulus clouds. The software program was used to solve the differential equation developed by Stommel (1947) and Austin & Fleischer (1948) to calculate the lapse rates of temperature for three types of convection: dry, moist (with no entrainment), and moist with entrainment. By comparing these three cases of convection, one can see the effect that condensation and entrainment of drier environmental air have on the temperature of a vertically lifted air parcel.

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3. METHODOLOGY

The development of Stommel (1947) and Austin & Fleischer (1948) provides the differential equation that models the entrainment process:

$$-\underset{A}{\frac{dT}{dz}} = \underset{B}{\frac{g}{c_p}} * \underset{C}{\frac{[1 + (Lw_s)/(R_dT)]}{[1 + (\epsilon L^2 w_s)/(c_pR_dT^2)]}}$$

$$+ \underset{D}{\frac{1/m(dm/dz)\ [(T-T')+L/c_p(w_s-w)]}{[1 + (\epsilon L^2 w_s)/(c_pR_dT^2)]}}$$

where

T = cloud temperature
T' = environmental temperature
z = height
g = acceleration of gravity
c_p = specific heat capacity of dry air
L = latent heat of vaporization
w_s = saturation mixing ratio in cloud
w = mixing ratio of environment
R_d = gas constant for dry air
ϵ = ratio of molecular masses of dry to moist air
m = cloud mass

Term A is lapse rate of temperature for any given process, B constitutes the dry adiabatic process, B*C constitutes the moist adiabatic process, and D is the adjustment to the lapse rate due to the effect of entrainment of cooler, drier environmental air into the rising moist air parcel. Depending on the conditions imposed, the lapse rate calculated in this equation could be dry adiabatic, moist adiabatic, or some intermediate value (call this the entrained rate). For example, if Term C and D are deactiviated, the air parcel cools at the dry adiabatic lapse rate, or if C is activated but not D, the parcel cools moist adiabatically. Finally, when both Terms C and D are activated, the effect of entrainment is incorporated into the convective process.

In this case, the convective process is initiated at a height of 3000m, corresponding to a pressure of 700mb, where the environmental temperature is assigned a value of 272°K. For simplicity, constant values of environmental lapse rate (6.5°K/km) and relative humidity (67%) were assumed throughout the layer from 3000 to 10000 m. The environmental pressure distribution was assumed to be hydrostatic. Standard calculations for other variables dependent on temperature, height, or pressure were incorporated into the model.

All of the appropriate constants and equations were then converted into two different *Mathematica* programs. The first program stated all the constants, defined each equation, and combined them to create the desired atmospheric process; the second program simultaneously solved the differential equations for temperature and pressure, then graphed the results for the values generated by the first program. Therefore, all the differential equations were solved and the results illustrated solely by *Mathematica*.

4. FINDINGS

Fig. 1 displays the results generated by *Mathematica* for three cases: Dry (no condensation, no entrainment), Moist (condensation, no entrainment), and Entrainment (Condensation with entrainment).
The lapse rate for the dry case (labelled D) displays a nearly constant value of 9.8°C/1000m throughout the layer, describing a parcel of unsaturated air rising dry adiabatically. When the condensation process is activated (labelled M),

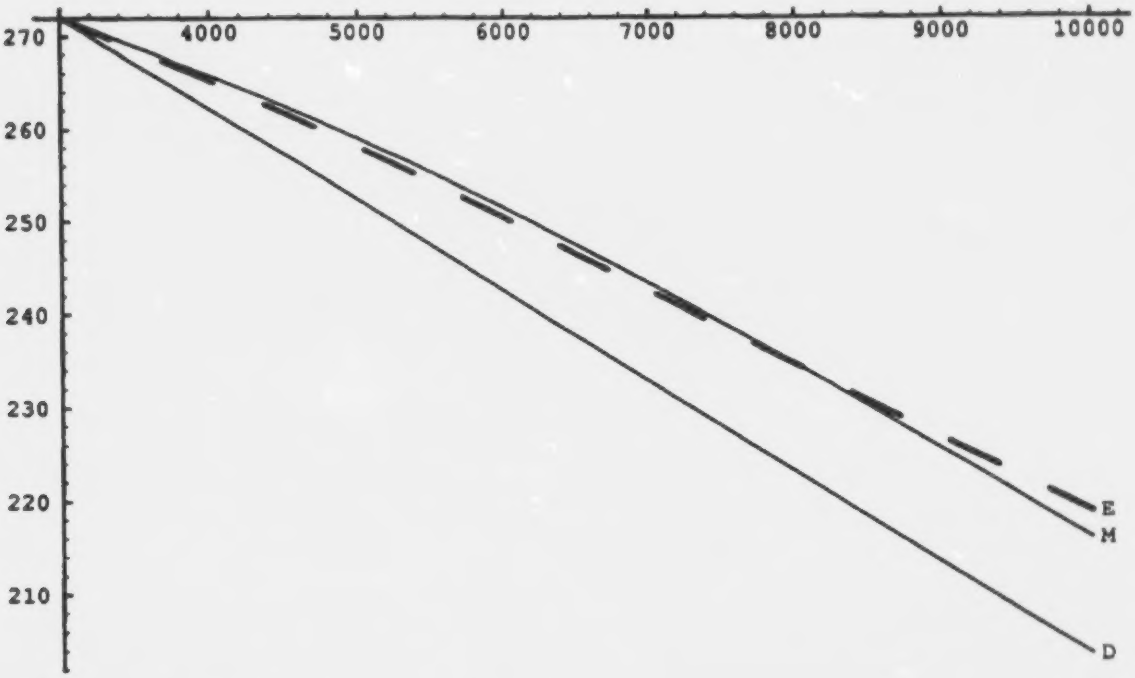

Fig. 1. Graphs of solutions to equation governing temperature change with height for convection with dry (D), moist with no entrainment (M), and moist with entrainment (E) conditions. Vertical scale is temperature (°K) and horizontal scale is height (m).

one sees the effect of latent heat release when excess water vapor is condensed, thereby reducing the rate of cooling. Finally, when the entrainment process is activated (labelled E), one sees the effect that entraining cooler, drier air has on the temperature lapse rate of the rising parcel. The parcel cools at a lesser rate than its unsaturated counterpart, due to latent heat release resulting from condensation, but at a higher rate than its saturated counterpart without entrainment because of the influx of cooler environmental air, which is also drier so less condensate is produced and less latent heat released.

The scientific aspect of this exercise has been very well known for nearly four decades due to the work of Stommel (1947) and Austin & Fleischer (1948). However, the intricacies of the entrainment process may be difficult for undergraduate students in their first course in atmospheric thermodynamics. A cursory glance at the defining equation (shown above) is not likely to shed much light of understanding to the beginning student. However, using a tool such as *Mathematica* can provide the student with the visualization of the solution, which can assist in the learning process. Further, once the program is finished, one can apply a variety of examples into the program to show the effect of changes in temperature, moisture content, pressure levels where convection is occurring, entrainment rate, etc. on the rate of cooling of the rising air parcel. More importantly, the process allows the undergraduate student to make the connection between the mathematics and science, and to understand that the mathematical processes employed in solving the problem are valuable tools for the scientist.

5. CONCLUSION

Software packages, such as *Mathematica*, can be a valuable tool in the undergraduate classroom. Such tools can greatly assist the instructor in demonstrating and displaying the solutions to sophisticated mathematical expressions that govern the behavior of physical phenomena. In undergraduate courses in meteorology and oceanography, there are often examples of phenomena that can be described in terms of complex differential equations. For the beginning learner, however, the treatment of the mathematics can be overwhelming and may create a serious obstacle in the learning process.

The entrainment process presented in this paper represents an example of an atmopheric process that CAN be modelled mathematically using *Mathematica*. By providing students with the tools to combine both the science and the mathematics, they are empowered to better understand physical processes and the mathematics needed to solve the equations governing such phenomena.

ACKNOWLEDGEMENT

The authors wish to acknowledge the Office of Naval Research which partially supported this project under grant ONR-94WR23012.

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P1.2

Using *Mathematica* to enhance learning of Oceanographic Processes: Wind-Driven Circulation

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1 Introduction

The governing equations of wind driven circulation have a rich history in oceanography as well as in mathematics. As early as the year 1492, Christopher Columbus had become aware of a westerly drift which was propelling his ship approximately forty miles per day. He logged this remarkable discovery, which was later termed the canary current, but did not attempt to explain its origin and physical basis. As the exploration of the Atlantic Ocean continued, the Gulf Stream and Labrador Current were discovered. Despite the discovery and exploration of these currents, it was not until 1769 that the natural philosopher Benjamin Franklin attributed the cause of this circulation to the force of the prevailing trade winds. Franklin's theory correctly linked oceanic circulation to wind but failed to account for the intensification which occurs along the western boundary of our oceans. In 1948, Henry Stommel attributed this intensification to the Coriolis Force, and after introducing a set of hypotheses that reduced the complexity of the governing equations of motion considerably, he proposed a mathematical model whose exact solution he was able to derive.

In this paper[1] we revisit H. Stommel's ocean model using *Mathematica*. We obtain the explicit solution to a boundary value problem for the stream function that serves as a vector potential for the velocity field. We then use *Mathematica*'s capabilities and draw the contours of this function as well as the relevant component of the vorticity vector. In addition, we employ a differential equation solver of this software package and follow the evolution of a string of particles as time evolves to gain insight into the type of deformations one encounters in this model.

2 Methodology

We imagine a rectangular ocean with the origin of the coordinate system at the southwest corner of the ocean. The y and x axes point northward and eastward, respectively. The shores of the ocean are located at $x = 0, x = \lambda$, $y = 0$, and $y = b$. The depth of the ocean, when standing still, is D. We assume there is frictional damping in the ocean of the form $-R\mathbf{v}$, where $\mathbf{v}$ is the velocity field. Finally, we assume that the wind stress generated in the ocean can be described by

$$-F\cos\frac{\pi y}{b}. \tag{1}$$

Following several simplifications of the equations of motion, which are described carefully in Stommel [1948], we find that the steady-state solutions of the governing equations for a rectangular ocean in a rotating frame satisfy the forced **Poisson** equation

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \alpha\frac{\partial\psi}{\partial x} = \gamma\sin\frac{\pi y}{b}, \tag{2}$$

where ψ is the stream function for the flow, and

$$\alpha = \frac{D}{R}\frac{\partial f}{\partial y}, \qquad \gamma = \frac{F\pi}{Rb}. \tag{3}$$

f in the above equation models the Coriolis force. We assume that the dependence of f on y is linear so that α is a constant. The boundary conditions for (2) are

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$$\psi(0,y) = \psi(\lambda,y) = \psi(x,0) = \psi(x,b) = 0. \qquad (4)$$

After applying separation of variables and satisfying the boundary conditions we find that the stream function $\psi(x,y)$ is

$$\psi(x,y) = \gamma\left(\frac{b}{\pi}\right)^2 \sin\frac{\pi y}{b}\left(pe^{k_1 x} + qe^{k_2 x} - 1\right), \qquad (5)$$

where p and q are

$$p = \frac{1 - e^{k_2\lambda}}{e^{k_1\lambda} - e^{k_2\lambda}}, \qquad q = 1 - p, \qquad (6)$$

and k_1 and k_2 are the roots of the quadratic polynomial

$$k^2 + \alpha k - \mu^2 = 0. \qquad (7)$$

3 Discussion

We use the original parameter values of Stommel, 1948:

$$\begin{aligned} \lambda &= 10^9\text{cm}, \\ b &= 2\pi \times 10^8\text{cm}, \\ D &= 2 \times 10^4\text{cm}, \\ F &= 1\,\frac{\text{dyne}}{\text{cm}^2}, \\ R &= 0.02 \\ f(y) &= 10^{-13}y. \end{aligned}$$

We nondimensionalize the independent variables x and y by the length and the width of the ocean and reduce the computational domain to that of a unit square ocean. With these modifications, expressions (1)-(7) are now ready for several applications on *Mathematica*. We begin by inputting the above parameters into this software, evaluate (3) symbolically (so that both cases of stationary and rotating oceans can be analyzed simultaneously), find roots of (7) symbolically, and define the stream function ψ. Once this function is known explicitly, a large amount of information concerning this flow is at our finger tips.

Figure 1 shows several level-curves of ψ and is the standard graph obtained by Stommel in his classic paper. This figure, which is obtained by running the internal command `ContourPlot` of *Mathematica* on (5), basically traces the paths of fluid particles. Even though it is color coded to show the intensity of the level curves, this graph does not readily demonstrate how parcels of fluid are being deformed under the action of the flow. To get that level of information one must bring time back into the picture. Figure 2 shows the paths of several particles after all particles have evolved the same amount of time. This figure is a consequence of solving the nonlinear differential equations

$$v_1 = \frac{dx}{dt} = \frac{\partial\psi}{\partial y}, \qquad v_2 = \frac{dy}{dt} = -\frac{\partial\psi}{\partial x},$$

with initial conditions corresponding to the initial positions of the particles. The above system of differential equations is solved using the `NDSolve` routine of *Mathematica*. It is interesting to note that Figure 2 carries more information with it than Figure 1 in that not only it gives us the general geometry of the flow, it also provides some insight into how a filament of fluid is being deformed under the action of the flow. Finally, Figure 3 shows the graph of the third component of the vorticity vector (the figure is rotated to give a better viewpoint). As expected, this figure shows that the vorticity is nearly constant, except in the narrow region near the boundary $x = 0$ where it increases rather sharply.

4 Conclusions

The findings in this paper are not new, although their determination has become more tractable because of *Mathematica*'s capability to draw contours well, solve complicated differential equations, and symbolically compute curl of velocity vectors. These features allow one to introduce the 1948 model of Stommel rather early in a student's undergraduate education.

It is worth emphasizing that it is not that the individual calculations that lead to Figures 1–3 are difficult to carry out, although the scope of these particular computations is perhaps beyond a facility such a symbolic calculator. It is the fact that software packages such as *Mathematica* have a wide range of mathematical applications assembled in one space and make it feasible to attempt to attack a partial differential equation such as (2). It is hoped that after having gone through such an exercise that

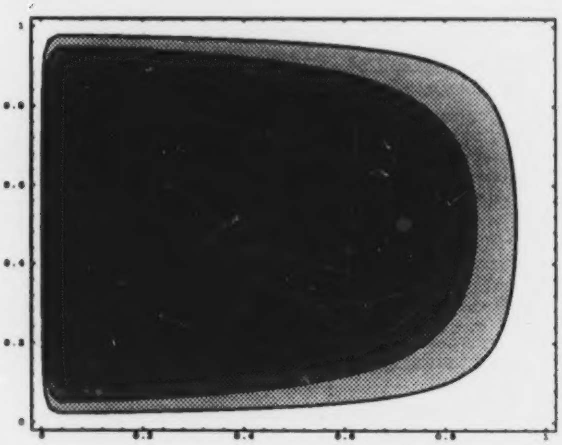

Figure 1: Particle paths in a rotating ocean.

it is not hard to convince a student that such a tool could be useful in one's entire education.

The equations of wind-driven circulation provide just one example of many oceanographic systems that lend themselves to the above style of analysis. It is hoped that projects such as these allow students to discover the natural role that advanced mathematics plays in describing fundamental processes in nature.

5 ACKNOWLEDGEMENT

The authors wish to acknowledge the Office of Naval Research which partially supported this project under the grant ONR-94WR23012.

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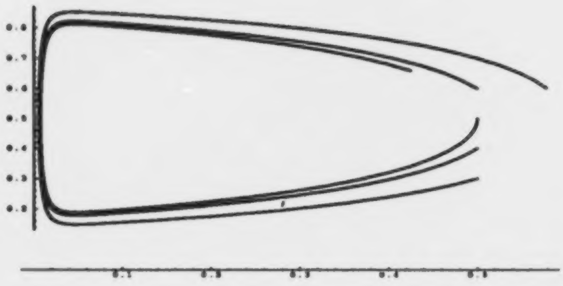

Figure 2: Location of three particles at a later time. Note that these particles, which are aligned vertically at time zero, are no longer aligned at the later time.

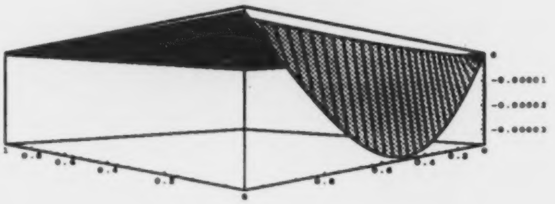

Figure 3: The graph of $\nabla \times \mathbf{v} \cdot \mathbf{k}$, the nonzero component of the vorticity.

P1.3 A MULTIDISCIPLINARY APPROACH FOR TEACHING ABOUT ENSO: APPLYING THE FIVE THEMES OF GEOGRAPHY TO TOPICS IN METEOROLOGY AND OCEANOGRAPHY

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1. INTRODUCTION

Current educational reform efforts in science and social studies emphasize student assessments which utilize hierarchial critical thinking skills as well as individual and cooperative student performance. Teachers are now accountable for both the content and performance achievement of their students. A suggested method for meeting state and local mandates to work together is through geography. As a discipline geography provides a variety of topics for study which emphasize the physical science as well as the human element. By working together science and social studies teachers can provide students with a more complete understanding of a topic. Furthermore, students become aware that neither scientific nor geographical issues exist in a vacuum. Global climate change is an issue which is relevant to both science and social studies. The El Nino-Southern Oscillation (ENSO) is an example of a global climatic phenomenon that is rich in both scientific and social issues that can be best understood by utilizing interdisciplinary teaching. The intent of this paper is to provide the precollege teacher with a tool to develop the full impact of this phenomenon from both a scientific perspective and a broader social context.

2. SCIENTIFIC DISCUSSION

The El Nino-Southern Oscillation is an intriguing process coupling both oceanic and atmospheric processes. To understand ENSO one needs to start with the conditions that precede its occurrence. Under normal circumstances the prevailing surface wind currents in the tropical Pacific are the Tradewinds. These easterly winds are generated by a pressure distribution in which high pressure is observed over the eastern Pacific (off the South American coast) and lower pressure further west. The winds, in turn, drive surface waters westward. These waters, supplied by the cool Peruvian current, are warmed as they traverse the Pacific. There is normally a well defined sea-surface temperature pattern across the tropical Pacific, easily observable in satellite imagery. In addition, due to the surface circulatory pattern across the Pacific, there may be as much as a 40 cm differential in sea level, sloping downward to the east.

This persistent air-sea pattern is sometimes disrupted, usually in December. The normal supply of cool, nutrient-rich water off the coast of Peru is displaced southward by a warmer equatorial countercurrent. In most years, this disruption is weak and short-lived, and normal conditions are easily resumed. However, in some years, the episodic warming is more pronounced and long-lasting. This anomalous behavior is called El Nino. The warmer waters invading the coast of Peru is coincident with a reduction in surface pressure over this region of the Pacific which alters the typical surface pressure gradient. The normal westward Tradewinds are replaced with a westerly wind flow, which, in turn, reverses the surface ocean circulation. During an El Nino event the warmer water from the western Pacific is driven eastward

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toward the South American coast. This cuts off the upwelling of the cooler, nutrient-rich waters which affects fishing in this region. In addition, the thermocline is pushed downward and the normal sea level pattern is altered, which allows the eastward propagation of Kelvin waves across the tropical Pacific Ocean. Weather patterns are also affected as the warmer waters fuel increased atmospheric convection and accompanying rainfall over the eastern Pacific.

Near the end of the warming period, which can last many months under extreme situations, the atmospheric pressure pattern begins to reverse and resume its normal distribution. This changing pressure pattern is accompanied by a resumption of the easterly Tradewinds and a restoration of the normal oceanic conditions. This periodic fluctuation in the surface pressure and wind patterns across the tropical Pacific is known as the Southern Oscillation.

The ENSO occurs at irregular intervals of three to seven years. One of the most extreme cases was during 1982-83, in which eastern Pacific sea-surface temperatures experienced up to 6°C warming, which had major biological and economic repercussions. Significant worldwide weather anomalies have been ascribed to this El Nino event.

While the intricacies of atmospheric and oceanic dynamics, as well as the interactions that affect climate, are beyond the comprehension of most students and perhaps many teachers at the precollege level, there are resources that one can employ to introduce the scientific aspects of ENSO at an appropriate level. For example, several popular publications such as *National Geographic*, *Weatherwise*, or *Scientic American* have presented scientifically accurate descriptions of ENSO written at a reasonable level of understanding for precollege teachers. In addition, agencies such as NOAA and NASA provide educational resource materials on ENSO as part of their outreach efforts. Further, video material from popular television broadcasts (e.g., the Public Broadcasting System, The Weather Channel, or the Discovery Channel, as well as educational resource corporations provide excellent visual display to help explain scientific aspects related to ENSO in an interesting and informative manner at an appropriate level for a general audience.

3. APPLICATIONS OF THE FIVE FUNDAMENTAL THEMES

The five themes of geographic instruction is a framework which can be easily utilized by both science and social studies teachers. When teachers adapt the same framework for developing lessons, continuity for the student is built in and therefore increases the student's potential for success in comprehending the relationship of the scientific forces and the human impact of climatic change. The five themes of geography are location, place, movement, human and environment interaction, and region. Utilizing the topic of ENSO as a case study, teachers can develop a unit which addresses the science as well as the human element of this phenomenon. What follows is a brief explanation of each theme as it pertains to ENSO.

Location. A mapping exercise can reveal to the student the patterns of the sea surface temperatures prior to and during the El Nino. Activities which emphasize location demonstrate the exact and relative location of the event.

Place. Since every place on the earth has physical and human characteristics which make it unique, this theme provides the teacher with the most opportunities to present students with interdisciplinary activities. In the case study of the El Nino, students should learn about the weather, climate, vegetation, animals, and land forms as well as the human features of culture and ideas. By doing so, students gain a greater appreciation for the impact of the El Nino on the lives of the people as well as the environment. In this case study it is vitally important for students to understand the drastic change that the ENSO brings to a particular region.

Movement. The focus of this theme is the spatial interaction of people, goods, ideas, and phenomena which goes on continuously since we live in a dynamic world. Activities which best illustrate this theme include mapping of the weather patterns, ocean currents, as well as charting the activity of the people affected by the El Nino.

Human-environment interaction. The cyclical relationship of this theme has the greatest potential for activities which have relevance to the lives of students. Lessons can stress how people prepare for the El Nino's effects on their homes and businesses. Students should explore the impact of the ENSO on national governments as well as the local and global economy. In short, students can learn how humans interact with the environment, and how the environment affects human life.

Region. The study of El Nino can easily be integrated into a unit which focuses on western South America and Australia. A region is an area defined by common characteristics and therefore, ENSO fits in nicely with studying the southeastern Pacific Ocean. If teachers decide to use the 1982-83 El Nino as a case study, a suggested activity is to examine the impact of the long term change in weather patterns on various regions of the world by comparing and contrasting the effects.

As a case study, El Nino provides both physical science and social studies teachers with the opportunity to work together to further the student's understanding of the impact of the physical forces on the daily life of people on both the regional and global levels.

4. CONCLUDING REMARKS

The five fundamental themes of geography are a suggested framework for teaching geography at the precollege level. The themes provide teachers with a tool that enables students to understand their world within a geographical context, by addressing the analytical questions: Where?, Why? and So What? These themes are also applicable in the science classroom, especially in the teaching of atmospheric and oceanic topics. Since atmospheric and oceanic phenomena are a significant part of our physical world, a student's understanding can be enriched by examining such topics from an interdisciplinary perspective. The five themes provide a mechanism to relate the interconnectedness of environmental phenomena with the lives of people.

Two recommendations made by the National Council on Science and Technology Education in Project 2061, a plan to address science literacy for all Americans, include:

* Being familiar with the natural world and recognizing both its diversity and unity, and

* Using scientific knowledge and ways of thinking for individual and social purposes.

The National Council is suggesting that the teaching of science be approached from a broader context, which is consistent with other trends in educational reform. Teaching ENSO is an example of an oceanographic/meteorological topic which lends itself to an interdisciplinary team approach to enhance students' educational achievement.

P1.4

Using *Mathematica* to enhance learning of Oceanographic Processes: Breaking of Waves and Burgers' Equation

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1 Introduction

Traditionally, the undergraduate curriculum in Advanced Engineering Mathematics is heavily geared towards the applications of linear mathematics to the standard engineering and science models. This is especially the case in the treatment of the solutions of linear partial differential equations, where by using normal modes and Fourier series one takes advantage of the student's familiarities with eigenvalues and eigenvectors and the principle of superposition to build the solutions of such equations. Nonlinear partial differential equations are often shunned because the above analogies generally break down and one needs to start with different building blocks. A notable exception is the method of characteristics for hyperbolic differential equations whose effectiveness is documented for both linear and nonlinear equations. Because hyperbolic equations are the primary examples of equations that support wave propagation, these equations enjoy a special status in oceanography, especially in the context of underwater acoustics and wave formation in shallow coastal waters.

In this paper[1] we consider the Burgers' equation as a prototypical hyperbolic partial differential equation and describe some aspects of its solutions and their behavior using *Mathematica*. We will outline some simple programs in the language of this software that demonstrate how waves break in this model and how one is able to predict the time of "blow-up" of a solution by measuring some of the geometric parameters in the initial perturbation that forms the wave.

2 Burgers' equation

The simplest nonlinear equation that resembles the type of equations that comprise the equations of fluid motion is Burgers' equation:

$$u_t + uu_x = 0. \tag{1}$$

We consider (1) together with an initial profile

$$u(x,0) = u_0(x). \tag{2}$$

The fact that the coefficient of u_x in (1) depends on the as yet unknown solution u causes the disturbance at different points in the initial datum $u_0(x)$ to propagate at different speeds. This in turn causes the solution to become multi-valued at certain appropriate points from which curves of discontinuity called **shock waves** emanate. Much of the mathematical research in the field of **conservation laws** (of which (1) is an example) since early 1950's has surrounded the understanding of solutions with discontinuities, or **weak solutions**, and the ramifications of weakening the concept of a solution.

A characteristic curve to equation (1) is a curve in the x-t plane that satisfies the differential equation

$$\frac{dx}{dt} = u(x,t), \quad x(0) = x_0 \in R. \tag{3}$$

We note that the above equation is a nonlinear ordinary differential equation in x. Moreover, since the function u is unknown at this stage, it is not clear how helpful (3) is in describing the solutions of

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(1)-(2). These points are in direct contrast with the case of linear partial differential equations where the equations that define the characteristics curves are linear with apriori known coefficients so that these curves are determined without any knowledge of the solutions and their qualitative properties are independent of the initial data.

In spite of the difficulties involving (3), this equation can be solved with the aid of (1). First let $x(t, x_0)$ denote the solution to (3). Let $f(t)$ denote the function u once it is evaluated along the characteristic $x(t, x_0)$ (we suppress x_0 in f for the time being), i.e.,

$$f(t) = u(x(t, x_0), t). \tag{4}$$

Differentiate (4) once to get

$$f'(t) = u_x \frac{dx}{dt} + u_t. \tag{5}$$

From (3) we have that $\frac{dx}{dt} = u$ so that (5) can be written as

$$f'(t) = u_t + u u_x, \tag{6}$$

which is zero by (1). Thus $f(t)$ must be constant in t. Going back to the initial profile of (2), we can determine this constant as the initial function $u_0(x)$ evaluated at x_0, i.e.,

$$u(x(t, x_0), t) = u(x(t, x_0), t)|_{t=0} = u_0(x_0). \tag{7}$$

Equation (7), in turn, simplifies (3) considerably. Since u is constant along a characteristic then

$$\frac{dx}{dt} = u_0(x_0), \quad x(0) = x_0 \tag{8}$$

so that

$$x(t, x_0) = u_0(x_0)t + x_0. \tag{9}$$

Equation (9) shows that the characteristic curves of (1) are straight lines, but unlike the case of linear partial differential equations, they are not parallel lines. The slopes of these lines depend on u_0 as well as x_0.

3 Two *Mathematica* Programs

We have found a parametrization of the solution to (1)- (2) in terms of its initial profile: The solution curve $(x, t, u(x, t))$ is given by

$$(x, t, u(x, t)) = (u_0(x_0)t + x_0, t, u_0(x_0)). \tag{10}$$

This parametrization lends itself naturally to the syntax of *Mathematica*. The following program shows how one uses (10) and get Figure 1 where the initial profile of the wave is

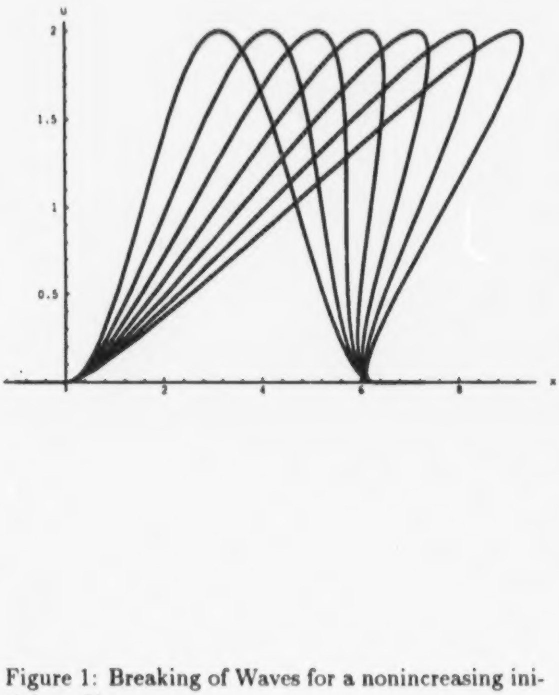
$$u_0(x) = \begin{cases} 1 - \cos x & \text{when} \quad 0 \le x \le 2\pi \\ 0 & \qquad\qquad \text{otherwise.} \end{cases} \tag{11}$$

The special feature of this u_0 is that it is decreasing in part of its domain, and thus, much like the waves in shallow waters approaching a beach, will cause the particles behind the crest to have faster speed of propagation and compress the ones in front of them.

```
u0[x_] = If[0 <= x <= 2 Pi, 1 - Cos[x], 0];


f[t_] := ParametricPlot[{u0[x0] t + x0,
u0[x0]}, {x0, -1, 2Pi + 1}, DisplayFunction
-> Identity]

snapshots = Table[f[t], {t, 0, 3, 0.5}];

output = Show[snapshots, DisplayFunction
->$DisplayFunction]
```

Figure 1 shows that the smooth initial profile u_0 in (10) is compressed from behind so that after t has reached a value near unity, the slope u_x has become infinite, and the differential equation (1) has lost its classical meaning. Another indication that something out of the ordinary is occurring with the initial profile (10) can be seen from Figure 2 where the characteristic curves corresponding to this initial profile are shown: The compression we alluded to above is clearly forming around $t = 1$ where characteristics with different slopes are intersecting. Since we showed above that the solution u remains constant along each characteristic and assumes the value of the initial profile on that curve, it is clear that when characteristics intersect the solution becomes multi-valued. This, in fact, is the classical definition of a shock wave. Figure 2 was obtained by running the following commands on *Mathematica*:

```
u0[x_] = If[0 <= x <= 2 Pi, 1 - Cos[x], 0];

output =
```



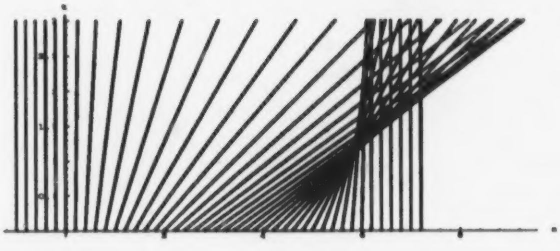


Figure 2: The characteristics corresponding to the initial profile in the previous figure.

Figure 1: Breaking of Waves for a nonincreasing initial profile.

```
ParametricPlot[Evaluate[Table[{u0[x0]t+x0,
t}, {x0, -1, 2 Pi + 1, 0.2}]], {t, 0, 3},
AxesLabel ->{"x", "t"}];
```

4 Discussion

The *Mathematica* programs listed above are just two examples of how one can use this software to gain insight into Burgers' equation. For example, even though the **ParametricPlot** command of *Mathematica* is capable of plotting the snapshots of the solution to any initial-value problem (1)–(2), it does not give information about $u(x,t)$ for a specific x. To compute u at a specific value of x we must invert the function $x(t,x_0) = u_0(x_0)t + x_0$ and find x_0 in terms of x and t. This in turn will give us the value for u because $u(x,t) = u_0(x_0)$. Here is how one accomplishes this on *Mathematica* for the initial profile in (10):

```
u0[x_] = If[0 <= x <= 2 Pi, 1 - Cos[x], 0];

invf[x_, t_] := FindRoot[u0[x0]*t + x0 - x,
{x0, -5}][[1,2]]

u[x_, t_] := u0[invf[x, t]]
```

In a different direction, one is often interested in finding the very first time characteristics in a figure such as Figure 2 intersect. The intersection of characteristics is intimately related to u_x becoming infinite, and it is possible to show that the latter occurs when

$$t = -\frac{1}{u_0'(x)}. \qquad (12)$$

Note that the value of t in the above relation is positive if u_0 is decreasing, pointing again to the fact that compression occurs in such profiles. The minimum value of (12) occurs when

$$u_0''(x*) = 0 \qquad u_0'''(x*) > 0. \qquad (13)$$

A package like *Mathematica* is quite helpful in finding roots of complicated functions such as $u_0''(x) = 0$ and testing the requirements of (13b).

5 Conclusions

We have given an indication of how *Mathematica* could be used as an aid to penetrate some of the complex structures of a nonlinear equation such as Burgers' equation. It is important to generalize the programs we have outlined above to two important systems in mathematical physics: the second order equation of nonlinear elasticity and the system of equations that govern motions in shallow waters. It was precisely the latter applications that prompted us to take up this investigation into the solutions of Burgers' equation as a first order model.

A capability of *Mathematica* that we were not able to touch upon in this paper is its ability to animate snapshots of functions such as $u(x,t)$. We have found that this capability helps enormously with elucidating features such as the deformations one sees in waves climbing beaches or strings vibrating with rather complicated initial profiles. This software package has also come in very handy in projects such as the description of surface gravity waves or interval waves generated between immiscible fluids, where an animated graph of a surface of a wave gets a point across where a string of rather complicated formulas does not seem to have done the job.

6 ACKNOWLEDGEMENT

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P1.5

WEATHER RELATIVE TO A RELATIVE

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Project ATMOSPHERE

1. INTRODUCTION

In recent years, considerable effort and curriculum revision have focused on interdisciplinary teaching styles and activities. Teaching or learning in isolation , be it topic, discipline, or field of study, does not complete either process. Not until it is related to the effects and impacts within the greater realms of earth, nature, or society, does one complete the teaching or learning processes. The breakdown of isolationism of the past is occurring in political, economic, and societal arenas. The term global has crept into almost all facets of life. Even education is recognizing the global nature of its future. It is imperative that we as teachers, at all levels, reach beyond the classroom. Technology is forcing contact with people across the country and around the world. We must learn about and try to appreciate the ways, needs, and culture of people, be it a New England lobsterman, Great Plains rancher, or Northwest logger. In fact, these boundaries have dissipated as they expand around the world to include all people, lifeforms, and processes.

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In addition to expanded needs of understanding is the growing availability of new materials and technology that can be used in the teaching/learning process. With the explosion of computers as processors and related devices for communication and data storage, new opportunities are emerging almost daily. This results in new challenges as we seek ways to successfully integrate these tools. Finally, I am now seeing cracks in the isolating we/they relationship of educators and the community. Education exists not only in schools, but also at home and throughout society. Schools only formalize it in place and time. The collaboration of school and home can enhance both portions to a greater gain. Both have something to offer and both need to be willing to listen. A third segment, that of business and industry, is gradually being brought into the equation. Organizations, such as the AMS, and scientists are now having a very positive impact on education with up-to-date information and materials. These groups can keep education aware of workplace needs, indicate evolving needs, and provide real-time applications of concepts being taught. Education must form partnerships, not succumb to paranoia. But, before any change or development can happen, one major event must transpire. It is simply a change in attitude. This is the primary goal of my workshops and courses for educators. If this can be achieved, there is no limit to the creativity of the individuals. The activity demonstrated is a result of a belief that says "even if we are doing the best possible job today, the parameters are changing daily, resulting in a need for constant development." Education is a process with the only constant being change. The display will show a student activity bringing together many of these components.

2. ACTIVITY

The "Relative to a Relative" activity involving a relative or friend, brings together various school subject areas, research skills, family members, and presentation skills and creativity. The objectives are for the student to learn about the weather, geology, and general environment of some place in the U.S. through a relative or friend. The directions are simple and provide freedom for the development of various products. The process is: (1) discuss concept with family and identify a relative to contact, (2) determine address and contact relative, (3) explain activity and ask for a couple of pictures (snapshots) of the area where he/she lives, (4) create street and area maps of the location using computer/CD-ROM program Street Atlas USA (DeLorme, 1993), (5) research from texts and tables the geology and climate/weather conditions such as monthly temperature and precipitation. From this information and material, the student develops a presentation using any of a variety of forms. The activity takes time for the student to reach the final product. The products will vary with the imagination and skills of the individual students. The process is as important as the product, reflecting that learning is itself a process.

3. CONCLUSION

This activity, and others I am developing, integrate science with other disciplines like geography, economics, math, communication skills, and other subjects, as well as the use of technology. I have found that this activity supports the concept that greater learning is achieved when the goal is the sum of the parts, the individual topics and disciplines involved. Examples of products will be displayed and discussed.

P1.6

AIR - SEA INTERFACE EDUCATION

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AMS Maury Project

1. INTRODUCTION

The Maury Project is the new education initiative of the American Meteorological Society, focusing on physical oceanography. With primary funding by the National Science Foundation, it combines the outstanding human and scientific resources of the AMS, U.S.Naval Academy, National Oceanic and Atmospheric Administration, and the State University of New York at Brockport. The three year program will involve a total of 72 precollege teachers in the two week summer training sessions at the U.S.Naval Academy in Annapolis, MD. Under the leadership of Prof.David Smith (USNA), instructional sessions and activities are conducted by USNA and NOAA personnel. Participants will lead local, regional, and national workshops for educators throughout the country. In addition to the training and resource materials provided, two teacher-training modules will be developed yearly for the field site workshops. A national network of these peer-trainer participants will expand each year and, through interaction with present AMS - Atmospheric Education Resource Agents, enhance the flow of scientific oceanic and atmospheric information to educators across the nation.

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Over a century ago, the U.S. Navy's Matthew Fontaine Maury collected, organized, and published information on the world's oceans. Now, with AMS leadership and the cooperation of other agencies, efforts are under way to make available the latest physical oceanographic information of the world's oceans to educators and students.

2. TRAINING PROGRAM

For two weeks in July, twenty-five Maury Project participants from all regions of the country, including Hawaii, gathered at the U.S.Naval Academy to participate in a vast array of seminars, activities, and field trips pertaining to a variety of topics in physical oceanography. Equally diverse were the educational backgrounds of the participants, ranging from elementary to high school and community educators as well as degrees from BA to PhD. This diversity of location and teaching level aided in the discussions of material and how it could be applied in different teaching situations. Effective peer-training must address the varied needs of the educators.

Multiple means, methods, and media were used by the instructors. Of particular importance was the great knowledge base of the USNA instructors, both in content and experiences. It was unique to learn from these instructors through interaction and not dominance. Each participant presented a concept demonstration, developed with the assistance of an academy instructor. Each day, an ocean or area of water was described as to conditions and significant features by an instructor with duty station experience in the location. Experience, knowledge of research, and a willingness to discuss ideas with participants made for great learning experiences. A variety of field trips reinforced concepts discussed and brought participants in contact with state-of-the-art facilities. Site visits included tours of NOAA headquarters with a presentation by Chief Scientist and former astronaut Kathy Sullivan, the NOAA Science Center, and the Naval Ice Center. Participants conducted sea water testing activities aboard an academy YP vessel, and sea/land impacts study at a shore site. Additional activities took place in academy wet lab and computer facilities. These many learning experiences raised the knowledge level of the participants, identified varied contacts and resources, and increased the desire to learn more about topics in the sessions.

3. TEACHER-TRAINING MODULES

Two ocean related modules were developed this year involving wind-driven surface currents and density-driven currents. Each of these was tested by the participants, followed by a critique and evaluation. The effect of the atmosphere on the ocean water brought out the importance of the interaction of the atmosphere and hydrosphere. The surface currents activity focuses on major ocean basins, discussing current names, locations, impact forces, speed and direction of movement, and climatic influences. The density activity examines the temperature and salinity of various water masses of the Atlantic Ocean. It looks at their origin, movement, and dissipation. Each module also contains sections of scientific concepts and understandings concerning the topic as well as reference publications. These modules will be used in the peer-training workshops.

4. CONCLUSION

The Maury Project of the AMS set sail as a well prepared program that conducted an outstanding two week training session to a group of enthusiastic educators. The target of the project, physical oceanography, is an area of ocean study where recent and on-going research information is generally not available to the K-12 education community. It is imperative that valid information about the world's oceans is available if we are to understand the environment of planet Earth. It is also necessary to recognize the interaction of the various forces and processes. The Maury Project of the AMS, with an outstanding beginning, is a great effort to address a very large and important need in today's education.

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P1.7

SCHOOLS OF THE PACIFIC RAINFALL CLIMATE EXPERIMENT: BRINGING GLOBAL ISSUES TO THE LOCAL CLASSROOM

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1. INTRODUCTION

In its second year, the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) is bringing together students from around the Pacific (including Hawai'i), as well as students in Oklahoma, to participate in the gathering of valuable scientific data while studying local and global climates and the potential effects of global climate change.

2. DESCRIPTION OF PROGRAM

The goals of the SPaRCE program include both educational and science objectives. Participants in this program are currently measuring rainfall, temperature, dew point, and relative humidity, using research-quality instruments, on a daily basis. Not only is all data shared with all participants, but the data are also incorporated into a larger data base being widely distributed to scientists interested in climate studies.

In addition to being involved in a real research program, participants also receive video-taped lectures, workbooks, and newsletters, which help them understand basic atmospheric principals, phenomena such as El Nino, and a better understanding of climate change on Earth. The focus of much of the material is on tropical meteorology. Typical textbooks in use in the United States and throughout many of the Pacific island nations only discuss Mainland U.S. type of weather systems and tend to ignore topics. Because the tropical atmosphere is so important, it is beneficial to students in Mainland U.S. schools and well as from around the Pacific to have a better understanding of this region of the globe. Monthly question/answer sessions are held over the PEACESAT (Pan-Pacific Education and Communications by Satellite) radio communications network, which allows for direct interactions between students and scientists.

There are currently over 50 schools and technical centers involved in the SPaRCE program. Participants range from elementary school to technicians at some of the Pacific meteorological services around the Pacific. Both public and private schools participate in the program.

As the program expands it is anticipated that more instrumentation be added. Presently, two of the participating schools are using an experimental hand-held radiometer which measures total column ozone and total column water vapor. If this instrument proves to be reliable, a network of schools across the Pacific making these types of measurements would be invaluable to scientists.

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P1.8 THE ARM EDUCATIONAL OUTREACH MANUAL FOR OKLAHOMA TEACHERS

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1. INTRODUCTION

The Department of Energy is in the midst of the Atmospheric Radiation Measurement (ARM) Program, a decade-long effort to improve atmospheric models through development and testing of parameterizations of cloud and radiative processes (Stokes and Schwartz 1994). The ARM Program entails a major instrumentation effort at several worldwide sites.

The ARM Program's Southern Great Plains Cloud and Radiation Test Bed (CART) covers large portions of Oklahoma and Kansas. The focus of the ARM CART is the heavily instrumented Central Facility located near Lamont, Oklahoma. The Central Facility includes such diverse devices as vertical profilers, balloon launch facilities, Bowen ratio devices, and pyranometer arrays scattered around a 66 ha site. Several full-time personnel are employed on site. Additionally, several extended facilities are located around the ARM CART region.

The University of Oklahoma and Oklahoma State University are cooperating on the Educational Outreach for the Southern Great Plains ARM CART. This ongoing effort involves faculty, graduate students, and support personnel at the two universities and includes a variety of thrusts. The Educational Outreach's purpose is to provide ARM-related education to students ranging from grade school through graduate school. One of the key portions of 1994's work was the production of a Field Manual for teachers of middle school through high school students.

2. BACKGROUND

Naturally-occurring electromagnetic energy occupies an insignificant portion of the public school science curricula in Oklahoma; this is unfortunate given the importance of electromagnetic energy in the context of the current concerns regarding climate change. Most Oklahoma

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science teachers lack extensive knowledge of such concepts because it has not been stressed in their professional training.

The idea for an ARM Field Manual came from the experiences we have had at the Central Facility. The Educational Outreach has the responsibility of hosting tours of the Central Facility. Such tours generally last a couple of hours. From the educator's perspective, it is desirable to conduct tours which maximize informational content and to do this it is highly desirable to speak to groups which have basic familiarity with electromagnetic concepts. This is especially true considering the fact that many of the Central Facility's instruments are unfamiliar to most people and are measuring invisible components of electromagnetic energy or weather parameters far above the surface. In other words, much of the potential impact on the Oklahoma schools might be lessened because the ARM Program's work is outside of common experience.

In this context, we conceived of the Field Manual as pre-field-trip curriculum having the potential to make the field experience at the Central Facility more meaningful. In addition, the Manual can present the basic components of the ARM Program to teachers who cannot bring their classes to the Central Facility.

3. FIELD MANUAL COMPONENTS

The Field Manual is a loose-leaf notebook with several sections. The intent of the Educational Outreach is to work with a growing set of teachers over several years and the loose-leaf structure of the Manual allows updates, additions, and deletions of material without re-publication of the entire work.

The Manual is composed of several sections which are intended to act together to give the teacher an introduction to the ARM Program, an introduction to electromagnetic energy, a set of pre-field-trip electromagnetic experiments, an explanation of the Central Facility, and specific instructions as to how to arrange and take a tour. We are enthused about the materials because they provide the teacher with materials to teach basic science and then a way for students to directly observe the application of the science.

A short synopsis of the Manual's major sections follows:

3.1 Forward and Preface

The Manual starts with an introduction to the "big picture" of climate change and a rationale of its importance.

3.2 The ARM Program

This section explains the intent of the ARM Program, its worldwide study sites, and its presence on the Southern Great Plains.

3.3 The Nature of Electromagnetic Energy

One of our observations has been that, as a group, Oklahoma teachers do not have a strong background in electromagnetic theory. This section is a non-mathematical description of the nature of electromagnetic energy. Several pages of illustrations are included and the loose-leafed Manual allows these illustrations to be readily converted to overhead transparencies.

3.4 The Central Facility

The site near Lamont is presented as one of the best-instrumented outdoor laboratories on Earth. In that the Central Facility exists here because of the regional agricultural background of wheat and grazing lands, a short regional geography is included. A map of the site's instrument clusters is presented and each type of instrument is explained. The section contains two pages of captioned photographs showing the instruments. Finally, there are 20 site slides inserted in a plastic sleeve.

3.5 Preparations for a Field Trip to the Lamont Site

The Central Facility is a working scientific site governed by Department of Energy rules. Teachers are given specific instructions of how to contact the Educational Outreach and a listing of the major rules which must be observed before and during site visits. The section ends with mapped and written travel instructions to the site. An appendix contains forms which must be filled out prior to the field trip.

3.6 Preparations for a Trip to the Tallgrass Prairie Site

By design, the Central Facility is many kilometers from the nearest large city. It is several kilometers from the nearest paved road. As a result, a field trip represents considerable travel time for many school groups. The Tallgrass Prairie Preserve (TPP), a bison rangeland administered by the Nature Conservancy, is only 70 km northwest of Tulsa and more proximal to the population of eastern Oklahoma than is the Central Facility. Moreover, the TPP gives us an alternative to the Central Facility when working with grade school groups. The ARM Program and the Oklahoma Mesonet both maintain instrumentation at the TPP. With the help of Nature Conservancy personnel we have devised an ARM field trip to the TPP and have included an explanation parallel to that of the Central Facility.

3.7 Experiments

Besides the teacher's background to electromagnetic radiation, we have also included a set of "experiments" which can be performed by students before taking an ARM field trip. These experiments are in the form of four lesson plans with a short teacher's background, explanation sheets for the students, and lab work sheets for the students. The experiments highlight electromagnetic energy through use of diverse things such as sunglasses, sunblock, and thermometers -- we have attempted to relate objects and devices familiar to the students to the concepts of electromagnetic energy.

3.8 Bibliography

A short bibliography provides names of articles, brochures, and books which would be of use to the teacher wishing to learn more or a student working on a term paper.

4. ACKNOWLEDGEMENTS

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P1.9

INTRODUCING THE MODERNIZED NATIONAL WEATHER SERVICE TO PRIMARY AND SECONDARY SCHOOLS

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1. INTRODUCTION

The future modernized National Weather Service will offer unprecedented advances in weather services to the Nation by the end of this decade. Highly trained meteorologists and hydrologists utilizing sophisticated processing and communications systems will fashion a new approach for observing, analyzing, and predicting the state of the atmosphere. This article will illustrate for both primary and secondary school educators how the modernized National Weather Service (NWS) will utilize recent advances in Doppler radar technology, satellites, superspeed computers, and automated weather observing systems to be the foundation for tomorrow's forecasts and warnings.

2. HISTORICAL PERSPECTIVE

The National Weather Service has a long history of striving to balance new technology to observe and understand the atmosphere in order to achieve more uniform weather services across the Nation. In 1870, the agency initially operated under the Signal Service and became the Weather Bureau in 1891. At this time, it was transferred to the Department of Agriculture. Increased responsibility of the Weather Bureau to provide weather services to civilian aviation later prompted the transfer of the Weather Bureau to the Department of Commerce. In July 1970, the name of the Weather Bureau was officially changed to the National Weather Service. It was placed under the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce where it remains today (Grice, 1992a).

Technological advancement and research in the science of meteorology and hydrology has increased dramatically over the last two decades. Improved warning and forecast services can only become a reality if obsolete and unreliable existing systems are replaced. Therefore, the Department of Commerce has set an ambitious goal to modernize the National Weather Service. The current modernization and associated restructuring process will improve forecasts, provide more timely and precise severe weather and flood warnings, and permit a more cost effective operating structure for the Nation by the turn of the century.

3. WEATHER RADAR TECHNOLOGY

During the late 1940's and 1950's, the main contribution to Weather Bureau operations was in the area of radar meteorology. Military surplus radars were the first to be renovated to detect precipitation echoes.

This is accomplished by transmitting a short pulse of electromagnetic energy and measuring a small fraction of energy scattered back to the radar by a storm. This is similar to being in a dark room and shining a flashlight beam toward a wall mirror some distance away. The amount of reflected light received is analogous to the strength of the returned signal measured by the radar. This reflectivity data gives an indication of the rainfall intensity and potential presence of hail. The time difference between when the energy pulse is transmitted and returned, tells the radar observer the distance to the precipitation echo. The process of transmitting and receiving hundreds of energy pulses each second provides a detailed map of the storms intensity.

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Information gained from these World War II vintage radars eventually led to the formation of today's network of surveillance radars. However, these radars which are based upon nearly a half-century old technology have become obsolete and difficult to service.

4. DOPPLER RADAR

During the 1970's, Doppler radars were employed in storm research programs to study severe thunderstorms. This latest tool in storm detection is like conventional radar in that it scans the sky from near the Earth's surface to the top of the atmosphere for precipitation targets. However, the Doppler radars narrower beamwidth enables detection of precipitation targets at much greater sensitivity levels and distance than is possible with conventional radars and their much wider beamwidth. This is comparable to shining a flashlight versus a laser beam if each could detect precipitation droplets.

In addition, the Doppler radar has the added capability of detecting the speed of targets moving either toward or away from the radar. This velocity data is useful to forecasters in detecting wind speed and movement within a thunderstorm.

It does this by measuring the frequency change in the transmitted pulse caused by the target's motion. This change in frequency is similar to the sounds created by a train whistle or police car siren as it approaches and moves past a given location. These frequency changes are called Doppler shifts, from where the Doppler radar gets its name (Ray, et al., 1979).

The greatest value of Doppler radar will be to identify mesocyclone development and strength during the early life cycle of a tornadic thunderstorm. A mesocyclone refers to a vertical column of rising counterclockwise rotating air. It is often observed in the middle portion of severe thunderstorms and may descend to the lower portion of the cloud base with tornado formations. Nearly all significant tornadoes are preceded by a strong mesocyclone in the middle levels where the largest hail and strongest rotation of wind occurs. Recognition of this rotating column of air will permit warnings to be issued a number of minutes prior to tornado touchdown.

The Weather Surveillance Radar - 1988 Doppler (WSR-88D) system will have the ability to display both reflectivity and velocity data on high-detailed city map backgrounds. This will allow forecasters to issue very specific warnings and statements than ever had been possible before. It will also be helpful in evaluating observer's reports of rotating funnel clouds. The WSR-88D system will also provide precipitation amount estimates that are vital to hydrologic forecasting of potential flooding. Hydrologists will use this data to specify affected areas drained by a river at its tributaries and to better define to the meteorologist the location of flash flood threat areas.

Another valuable forecasting tool of the WSR-88D system is its ability to operate in clear air. The Doppler radar has sufficient sensitivity to detect frontal systems and old thunderstorm boundaries between observation sites. This information will be used by forecasters to outline areas where thunderstorm development may occur in the future. The added ability to plot wind velocities at different elevations above ground level will be valuable in determining the strength and turning of the wind with height to support thunderstorm development.

The National Weather Service plans to operate 121 Doppler radar systems with an additional 40 radars located at Federal Aviation Administration and Department of Defense sites. This network of Doppler radars will provide significant improvements in uniform coverage over the present day radar network.

5. SATELLITES

The Weather Bureau entered the satellite age in the 1960's where the importance of satellites to observe the world's weather soon became apparent. In the 1970's, geostationary weather satellites that were launched provided meteorologists with continuous observations over much of the western hemisphere.

A new generation of Geostationary Operational Environmental Satellite (GOES) will aid forecasters in detecting dangerous storms not easily recognized with current satellite imagery. The new satellites will provide a more detailed and refined image of clouds. The GOES system will be able to zoom in on significant weather events as frequently as every six minutes while continuing to provide overall coverage of visible and temperature sensitive infrared imagery. Additional sensors will also be scanning and relaying important weather information of cloud patterns, cloud-top measurements, and profiles of moisture in the atmosphere back to Earth. Dual-satellite coverage will be assured throughout the remainder of this century with improved GOES satellites.

6. COMPUTER TECHNOLOGY

During the Signal Service years little meteorological science was used to make weather forecasts. Instead, weather which occurred at one location was assumed to move into the next area downstream. Weather forecasts were simple in nature and usually only contained basic weather parameters like clouds and precipitation. One of the more important advances for the Weather Bureau was the advent of the teletype system. Use of the teletype spread rapidly and increased the Weather Bureau's ability to transmit warnings or critical observations.

The development of computer technology in the 1950's paved the way for the formation of complex mathematical weather models to aid meteorologists in forecasting. The first operational use of these computer models resulted in a significant increase in forecast accuracy.

Warnings and forecasts prepared by National Weather Service offices in the next decade will rely heavily on the basic analysis and guidance products provided by the National Meteorological Center. These products result from numerical models of the atmosphere run on high-speed computers. This increased demand will require the utilization of super computers capable of processing meteorological data an order of a magnitude greater than the current computer capabilities.

Today National Weather Service offices communicate and process on site information with the Automation of Field Operations and Services (AFOS) system. However, AFOS does not have the capability to process satellite information or the extensive observational network that will arrive with the newer technology.

The nerve center of communications for every Weather and River Forecast Office will become the Advanced Weather Interactive Processing System (AWIPS). The AWIPS system will be a state-of-the-art interactive workstation that will assemble, process, and display observational data and guidance from National Centers with satellite imagery and local radar coverage.

AWIPS will aid forecasters in making rapid decisions, prepare warnings and forecasts, and disseminate these products to the users in a timely manner. AWIPS will also assist hydrologists at River Forecast Centers in data collection and processing, execution of hydrological models, and product formatting and dissemination.

7. RADIOSONDE DATA

During the early 1900's, the Weather Bureau utilized kites to measure temperature, relative humidity, and winds in the atmosphere. By the early 1930's, kites were becoming a hazard to airplanes in flight and were replaced by airplane observations.

Prior to World War II, the meteorologists understanding of the weather was greatly enhanced by the development of the radiosonde. These inexpensive meteorological instruments and radio transmitters were carried aloft by balloons and greatly increased the science of weather forecasting. Even today, the most basic data source for any weather forecasting system remains the radiosonde. Upper air balloon launches of these radiosondes occurs twice daily, during the morning and evening.

NOAA has defined a program to investigate new technologies for the development of a radiosonde system for the next century. The new radiosonde balloon system will use advanced navigational tracking techniques and provide real-time digital upper air sounding data of wind measurements.

Another step in supplementing the national radiosonde network is the utilization of wind profilers. A vertical wind profile consists of a set of wind speeds and directions at various heights. Relatively, low power Doppler radars will measure the atmospheric wind above a profile site and provide a plot of the wind speed and direction at hourly intervals. This data can be used to augment upper air observations, identify jets or strong winds in the atmosphere, and determine the location of fronts, low pressure troughs and high pressure ridges.

8. AUTOMATED SURFACE OBSERVING SYSTEM

During the early and mid 1800's, weather observation networks began to grow and expand across the United States. With the advent of the teletype, weather observations from distant points could be rapidly collected, plotted, and analyzed at one location.

Today, routine surface observations are collected at nearly 250 locations. A joint effort of NOAA and the Federal Aviation Administration will greatly expand the observational network with the utilization of nearly 1000 Automated Surface Observing Systems (ASOS). These units will provide surface observational data of atmospheric pressure, temperature, wind direction and speed, type, intensity and accumulation of precipitation, runway visibility, and cloud height ceilings on a continuous basis 24 hours a day.

This information will flow directly to NWS offices as well as to the local airport control towers to alert forecasters and pilots of significant weather changes.

The national capability to observe and transmit critical changing weather conditions almost as they occur represents an important enhancement of improving warning and forecast services.

9. MODERNIZED STRUCTURE

The first general weather forecasts originated at Washington, D.C. and were issued twice daily and covered a 36 hour duration. During the early 1900's, five district offices were formed to receive telegraphed observations from across the country. Around 1900, the Weather Bureau continued to steadily increase the number of district offices and began issuing general weekly forecasts to help farmers plan agricultural activities. In 1940, these forecasts were replaced by a more detailed 5-day forecast. Today's 3-to-5- day forecasts are as good as the 1-to-2 day forecasts of a decade ago.

The present organization of a national network of Weather Service Forecast Offices and smaller Weather Services Offices is about a quarter of a century old. The future structure of the NWS will include a network of 115 modernized Weather Forecast Offices (WFO) strategically located across the United States. These 24 hours-per-day offices will provide a range of weather warnings, products, and services in an assigned area of responsibility.

A Meteorologist-In-Charge (MIC) will have the responsibility for each Weather Forecast Office. Each WFO will have both a Scientific Operations Officer (SOO) and a Warning Coordination Meteorologist (WCM). The SOO will play a vital role in assisting forecasters with the new technology and will be a strong link between the research community and operational forecasting. The WCM will assume the leadership role in storm spotter training, coordinate the stations warning program with local, state, and federal agencies, and will assist in the administration of the forecast office. The core staff of professional meteorologists will be assigned the task of evaluating vast amounts of integrated data, analyzing the processes and events that will affect an area of responsibility, and apply scientific and technical expertise in a broad spectrum of immediate decisions. The public hydrologic warning, forecast, and information program will be managed by a Service Hydrologist strategically located at selected WFO's. Meteorologist technicians will also require different skills determined by peak service demands and maximum weather activity.

The Nation's need for improved management of water resources and more accurate flood forecasting will continue to increase during the 1990's. Thirteen River Forecast Centers (RFC) will be collocated with a WFO in order to enhance the collaboration between meteorologists and hydrologists. A Hydrologist-In-Charge (HIC) will have the responsibility for each RFC including the Hydrometeorological Analysis and Support Group (HAS). This group of hydrometeorologists will facilitate the integration of meteorological information into hydrologic products and services. Additional research and technical support will be provided by a Development and Operations Hydrologist (DOH).

Historically, RFC's have operated on a one forecast cycle per day. This was based upon manual observations taken in the morning. RFC's will begin to operate an average of 16 hours-per-day and expand to 24 hours during periods of flood threat and seasonal peak work loads. Hydrologic forecasts will be issued as frequently as every six hours to keep pace with changing weather and soil moisture conditions.

10. CONCLUDING REMARKS

The modernization and associated restructuring of the National Weather Service will feature improved services through the effective use of new technology. Productivity and service improvements will be achieved by automating observation and communications duties, and freeing trained professionals to concentrate on analyzing and forecasting local atmospheric and hydrologic events. As we enter the next century, the combination of a highly skilled professional workforce, new science, and advanced technology will result in more timely and precise severe weather and flood forecasts and warnings for the Nation.

11. ACKNOWLEDGEMENTS

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P1.10

THE EXCITEMENT OF METEOROLOGY! AN INTERACTIVE STUDY IN THE GEOSCIENCES

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1. INTRODUCTION

During the period from 1966 to 1988 the percentage of first-year college students intending to major in science or math fell by one-half (Green, 1989) and continues to decline. Today, only 2.4 percent of students plan to major in the physical sciences, and only 0.1 percent in the atmospheric sciences (*The Chronicle of Higher Education*, January 13, 1993). Although the weather has a tremendous and often obvious impact on the nation's economy, the subject is either not taught or is given only a light treatment as part of an earth science course and is partly responsible for the decline.

Project Atmosphere (see Smith et al., 1994) has been an important step towards amelioration of this problem. By focusing on improved education of K-12 science teachers, and by offering programs and services through state representatives, it provides students with a more informed instructor. Project LEARN (Gellhorn and McLaren, 1994) provides a similar program for middle and junior high school teachers. However, these and other programs do not address the broader population of students who may be interested in studying meteorology.

2. EXCITEMENT OF METEOROLOGY

A summer course entitled "The Excitement of Meteorology for Young Scholars" has been proposed to offer those students a chance to study meteorology. Through instructional sessions, laboratories, field trips, and peer contact students will be exposed to the concepts of atmospheric motion, the development of storms, and the practical application of meteorology during a one month period.

2.1 *Goals and objectives*

The summer course is intended to help students make their own career decisions and to foster their interest in the sciences and meteorology. The goals and objectives of the course are to develop basic science skills, make students aware of the interdisciplinary nature of meteorology, provide students with the opportunity to see and hear the meteorologist as a researcher, teacher, and communicator, provide the necessary information and incentive for students to choose a career in meteorology or the sciences, make students aware of the various employment opportunities in the field, and show the moral and ethical responsibilities and importance of atmospheric science to society.

2.2 *Course Design*

The course is designed to teach atmospheric concepts and weather analysis and research methodology. Morning sessions will focus on building a foundation of the basic meteorological principles that the student will apply in laboratory sessions. These will be complemented by a series of field trips designed to increase students' knowledge of the field, its interdisciplinary nature, applications of research methodology in the work place, and guidance and incentive for career development.

The structure of the course has been designed to focus on basic meteorological principles the first week, the practical application of meteorology during the second week (including the educational training required), special topics and student projects the third week, and student project presentations and evaluations the last week.

The unifying mathematical, physical, and chemical principles of weather will be discussed in lecture and applied in laboratory assignments. The lab sessions will focus on the techniques utilized by meteorologists for data assimilation and interpretation, such as isopleth analysis. Field trips

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email address: pcroft@jaguar1.usouthal.edu will allow meteorologists and other scientists to describe their research and practical applications of operational and forecast meteorology.

Students will complete a group research project which involves much of the methodology learned in lecture and applied in the laboratory. A career in meteorology will be strongly emphasized as well as an appreciation of the importance of science, and the professionalism it must engender, and the role of scientists in the public domain.

Students will also prepare a "weather perceptions" questionnaire during their final week of the summer course. The questionnaire, designed by student groups at the end of their summer session, will address issues of public weather knowledge and perceptions. During the ensuing fall and spring, the students will administer the questionnaire to classmates, teachers, and the general public. The survey will allow each student to determine the level of "weather awareness" of the populace.

3. EVALUATION AND DISSEMINATION

The success of the course will be evaluated based on the caliber of student projects and several questionnaires to clearly identify strengths and weaknesses. An initial questionnaire (#1) will provide information on each student's level of preparation for the course and identify individual characteristics and abilities which will be important in group dynamics. A questionnaire given on the last day (#2) will be used to evaluate what students have learned and whether student interest in meteorology, or in their overall perception of science, has changed. Basic meteorological and science skills will be tested, examined according to the before and after questionnaire responses (#1 and #2), and evaluated subjectively from student reports and presentations.

Questions on basic skills will focus on basic knowledge, problem identification and solving, and analytical skills. Student understanding of the interdisciplinary nature of meteorology will be evaluated from their reports, presentations, laboratory work, and through their response to a separate questionnaire (#3) on their field trip experiences. This questionnaire will determine each student's understanding of the significance of the trips with regard to career exploration, ethical and moral considerations, and the role of scientists as communicators and decision makers.

A fourth questionnaire (#4), also given on the last day of the course, is intended to reveal students' desire to pursue meteorology or science as a career and employment opportunity; and will ask them to evaluate any changes in their level of interest in science and college. Questions will focus on any pre- or mis-conceptions of science and the student's own evaluation of self-preparedness to study meteorology. Students will be asked to rate their chances of pursuing meteorology and to rate their specific interests in meteorology and science.

Science teachers and guidance counselors involved in the students' course activities will be asked to prepare a qualitative evaluation of the significance of the program with regard to individual student's career planning and the relevance and impact of materials brought into the classroom by the student before, during, and after the student's summer participation.

Dissemination of project results will be made through local, regional, and national presentations and via electronic mail and educational bulletin boards (e.g., the GEOG-ED listserver) as appropriate. The intent of these activities is to provide important information and considerations on the nature of science instruction to K-12 teachers, undergraduate instructors, administrators, and academic and educational researchers. It is intended that the course will serve as a national model which may be implemented at the regional or local level by colleges and universities.

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P1.11 ON-LINE CLIMATE RESOURCES FOR THE CLASSROOM

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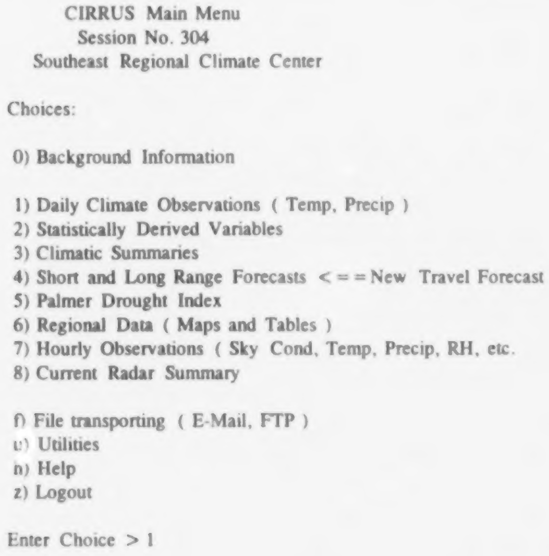
1. INTRODUCTION

The study of meteorology incorporates various aspects of diverse scientific disciplines. It therefore provides a useful tool to educate students in many fields including computer science, mathematics, and geography while simultaneously familiarizing them with the weather. The Southeast Regional Climate Center (SERCC) has developed an outreach program which emphasizes this multi-disciplinary approach to science education. The basis of this program is the use of SERCC's Climate Information Rapid Retrieval User System (CIRRUS) within the classroom.

2. CIRRUS CHARACTERISTICS

CIRRUS is a computer-based information system which allows rapid access to a variety of climate related products. This menu driven climate information system is accessible by subscribers through modem and Internet. An example of the main menu is given in Figure 1.



```
       CIRRUS Main Menu
         Session No. 304
    Southeast Regional Climate Center

Choices:

 0) Background Information

 1) Daily Climate Observations ( Temp, Precip )
 2) Statistically Derived Variables
 3) Climatic Summaries
 4) Short and Long Range Forecasts <==New Travel Forecast
 5) Palmer Drought Index
 6) Regional Data ( Maps and Tables )
 7) Hourly Observations ( Sky Cond, Temp, Precip, RH, etc.
 8) Current Radar Summary

 f) File transporting ( E-Mail, FTP )
 u) Utilities
 h) Help
 z) Logout

Enter Choice > 1
```

Figure 1. CIRRUS Main Menu

CIRRUS offers regional coverage for Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee, Virginia, Puerto Rico and the U.S. Virgin Islands. Data and information originate from the National Weather Service Weather Wire, the Climate Analysis Center, the National Climatic Data Center, and state weather networks. Data from over one thousand stations are obtained on a daily basis and archived in an historical data base. CIRRUS also provides reliable real-time hourly data from statewide agricultural and forestry networks (Alabama, Florida, Georgia, and North Carolina) as well as from federal agencies including the United States Geological Survey, the National Weather Service, U.S. Fish and Wildlife Service, National Park Service, and the U.S. Forest Service.

3. CLIMATE RESOURCES FOR THE CLASSROOM

3.1 Educational Projects

CIRRUS is an educational medium that provides economically and environmentally important climatic information in a timely and easily accessible manner. The system gives students the opportunity to observe and analyze the weather on a daily basis which enhances their understanding and awareness of their environment. So often education lacks the interaction between teacher and student, but with CIRRUS students get to experience the excitement of retrieving and displaying the weather data themselves. Once the data is obtained the teacher can also concentrate on using the data for specific lesson applications such as mapping, graphing, mathematics, statistics, even basic computer communication skills. Students can learn about their local and regional weather patterns while utilizing diverse educational tools.

Most of the data available on CIRRUS are in a tabular form (Figure 2) that can be downloaded in a standard ASCII spreadsheet format. This gives the teacher the freedom to use the data for a variety of educational purposes including graphing, mapping, and mathematical computing. Students or teachers can download any of the data at their convenience for any given time interval from hourly to annually. Students may then represent the data graphically and thereby improve their reasoning skills. Students may graph several parameters for several stations showing specific trends for their region. Students can spatially represent the data by plotting the values on a map which can teach them to differentiate geographical weather patterns.

```
Station: (088758) TALLAHASSEE_WSO_AP
Year=1994 Month=4:

year mm dd  tobs  prcp   tmax  tmin  mean  snow  depth
                  (in)   (F)   (F)   (F)   (in)  (in)
1994 04 01  24    0.00   70    36    53    0.0   0
1994 04 02  24    0.00   77    33    55    0.0   0
1994 04 03  24    0.65   80    37    59    0.0   0
1994 04 04  24    0.08   77    55    66    0.0   0
1994 04 05  24    0.00   79    51    65    0.0   0
1994 04 06  24    0.63   79    56    68    0.0   0
1994 04 07  24    0.00   73    45    59    0.0   0
1994 04 08  24    0.00   80    45    63    0.0   0
1994 04 09  24    0.00   82    61    72    0.0   0
1994 04 10  24    0.00   84    60    72    0.0   0
1994 04 11  24    0.00   85    58    72    0.0   0
1994 04 12  24    0.70   75    67    71    0.0   0
1994 04 13  24    0.42   75    67    71    0.0   0
1994 04 14  24    0.01   87    62    75    0.0   0
1994 04 15  24    0.00   85    71    78    0.0   0
1994 04 16  24    0.22   81    66    74    0.0   0
1994 04 17  24    0.00   81    51    66    0.0   0
1994 04 18  24    0.00   86    47    67    0.0   0
1994 04 19  24    0.00   85    55    70    0.0   0
1994 04 20  24    0.00   89    59    74    0.0   0
1994 04 21  24    0.72   83    63    73    0.0   0
1994 04 22  24    0.00   83    61    72    0.0   0
1994 04 23  24    0.00   70    63    67    0.0   0
1994 04 24  24    0.00   84    60    72    0.0   0
1994 04 25  24    0.00   86    66    76    0.0   0
1994 04 26  24    0.00   89    64    77    0.0   0
1994 04 27  24    0.00   90    63    77    0.0   0
1994 04 28  24    0.00   88    60    74    0.0   0
1994 04 29  24    0.00   86    61    74    0.0   0
1994 04 30  24    0.00   87    65    76    0.0   0

 Avg/Sum          3.43   81.9  56.9  69.4  0.0   0
* Data values are for 24 hours ending at time of observation.
```

Figure 2. Sample Monthly Product

3.2 CIRRUS Users

CIRRUS users include academic institutions, a variety of businesses, and researchers in both the public and private sector. The educational users range from elementary schools to the university environment. Figure 3 displays the number of logins during the past twelve months for each primary user group. Currently, the realm of use by the university community is greater than any other level of the educational system. It is widely used in research by university students and faculty around the region. CIRRUS is offered on-line in one university library with over 273 logins in eight months, so future plans are to expand this type use in other states. At North Carolina State University the Department of Soil Science, the School of Agricultural and Life Science, and the Geography Department all use CIRRUS. Other universities across the region are using CIRRUS in various departments such as biology, engineering, and geological science.

CIRRUS USERS
September 1993 - August 1994

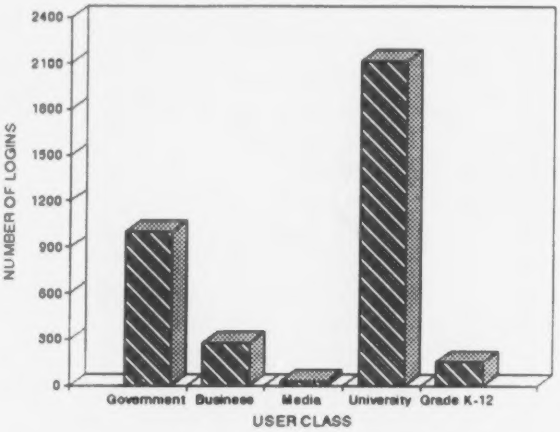


Figure 3. CIRRUS Logins: September 1993 - August 1994

4. CONCLUSION

There is valuable educational benefits from using a climate data access system such as CIRRUS in the classroom. It is expected that the range and number of educational applications for this on-line resource will greatly expand as people learn of its existence and availability.

Because of the wide range of use for climatological and meteorological data SERCC has kept the data somewhat standard. In the future SERCC hopes to encourage and expand use for primary and secondary education by improving the visual appearance of the data.

P1.12

Sharing Weather with Children:

A Guide for Meteorologist, Engineers, and Other Scientists.

by Steve Carlson, AERA-Project Atmosphere

The Job:

In the rapidly changing world of science and technology, the meteorologic community faces the challenge of aiding in the education of our nation's children. Many of you have already joined forces with the education world in attempting to meet that challenge. We must support weather education by providing resources, tools, materials, time, and building community support for teachers.

Your help is needed! One of the best ways to impact education is to become involved at the local level with the classroom. Teachers will welcome someone who has an in depth knowledge and understanding of meteorology. By sharing your expertise at the local level, you can help the students:

- Understand the positive and vital role weather plays in today's world,
- gain an understanding of the work meteorologist do,
- see meteorologist as real people,
- create interest in careers in meteorology, and
- help them to enjoy the natural world around them.

A few hours of your time can pay huge benefits. The purpose of this guide is to provide a few suggestions to make your visits more productive. Hopefully, by following these suggestions, you and the children will have a positive experience.

Survival Tips!

Before you go into the classroom:

•Decide on the strategy you will use.
Relate your presentation to the curriculum. Personalize the presentation with examples of what you do.

•Chose activities relevant to the children's needs and abilities.
Check with the teacher to see what students already know.

•Prepare for various kinds of reactions.
-Not all children will love you. Nor will all teachers have conservative discipline standards. Discuss what the plan of action will be if there is a problem. If you are presenting something on safety, or something of a sensitive nature, check with the teacher first. You don't want to be talking about how foolish a group of people were in a flood or hurricane, if someone in the class just had a relative die in such an occurrence.

•Organize your notes and materials in advance.
Make sure you have enough copies of any handouts or materials for everyone. Do a test run on any activity, game or experiment. Demonstrations should be done when safety is a concern, but hands on activities with the kids are much more effective.

•Don't talk over their heads.
Check over your lesson and substitute any words which can be simplified. Should you have difficulty finding an appropriate synonym, supply the teacher with the words in advance so the students have a chance to learn them.

•Arrive early.
Meet the teacher, aides and children in a more relaxed setting. Welcome them to the room whenever possible. It may also take you more time than you planned to set up, and to find the room. A major thought to keep in mind is to be prepared for the unexpected.

•Look for additional resources.
-Find out where students and teachers can follow-up your visit in the local area. Are there places they can visit, procure resources, organizations to join! What is available?

•Share yourself.
Let the children know that you are a real person. Personalize the lesson by starting with how you became interested in meteorology. What you find fascinating about your work. If you have children, talk about what you do with them at home. You might share what an average day is like in your business.

•Students must do.
Let the students take part in the lesson. Instruments you might consider common will be fascinating to children. Let them handle, question, and see how the instrument works whenever possible. Let them take measurements, analyze data, and draw conclusions. Being an oracle of wisdom in a classroom may leave you with an actual audience of only one.

•Let them do science.
The process of science is enjoyable. Let them experience it. Teachers with limited knowledge usually stick close to the book, so anyone guiding the student through the process is a hero.

•Ask questions instead of giving answers.
Just giving information instead of causing the student to think lead to the poor retention of information. The most students will remember in the long term is about twenty per cent of what was presented. If students have to do it, say it, and figure it out themselves, the retention gains can be incredible. Think about the things you really know! How did you learn them?

•Make your topic relevant to the student's lives.
Bring in examples of how meteorology effects us all. Show how it effects how we dress, live, and work. Believe me, if you are in snow country the students will want to know what signs to look for to have school closed. This is also a good time to discuss issues of safety.

•Don't surprise them.
If something unusual is part of your activity, tell them what to look for. If they are surprised or frightened, they won't observe or learn a thing. They may think it's great, but the only thing they will remember is the event, not the lesson.

•More than a memory.
Let the students take something home. Give them an assignment that will stimulate their own research and record keeping. If you build simple instruments, give them your address, phone, etc. so they can report back.

•Critique your lesson.
Bring closure to the activity before time runs out. See what they liked and learned. Ask the teacher for feedback. This feedback will be very valuable when you make another presentation. There is no better feeling of satisfaction than that of touching a kids life for the better.

•More than one.
A series of visits over a short time frame allows follow up and provides better activities. Don't try to cover too many concepts in one session. The lower the grade level, the simpler it should be. At the primary grade levels, just messing around and enjoying clouds, water, and the like may be the best.

TEACHING TIPS

Eye contact is important!
It makes the lesson personal. Consciously work from one side of the room to the other. The tendency of most is to work with the right side of the room or pay attention to the most extroverted.

Smile!
The students need to know you are friendly. An appropriate joke can spark their attention. If you have questions about the level of humor, let the teacher give you some examples.

Never a dull moment.
Be prepared. The quickest way to destroy a lesson is to have the student wait. Dead time is dangerous time! Use the teacher and volunteer students to distribute handouts. Know how you are going to do it in advance.

Hands please.
Many times everyone wants to talk at once. Don't let one student dominate. Bring out the best in everyone. Provide opportunities for everyone to demonstrate knowledge and you will have them in the palm of your hand. Don't call on someone and then ask the question. The only one thinking about what you are asking will probably be the one you called.

Be safe !
The students need to see good role models. Almost any experiment needs safety glasses. Be sure the safety glasses you wear are the same kind the kids wear! You'd never forgive yourself if a student lost an eye, or appendage under your care, regardless of any litigation.

Clear directions.
Make sure everyone understands the directions "before the task". After you start it is almost useless to try and get them to stop and listen. It takes a little bit of time, but it is time well spent.

Attention signal.
If you are doing hands on activities, prearrange a signal-a clap, toot, or light blink-when you want their attention. It may be critical to the lesson!

Pause.
Don't be an accordion style teacher where the last student off the bus or the one furthest away has no chance to learn ! If their attention or communication distance to you is not close enough to receive the information, you have diminished their chance of learning. Starting to teach before everyone is attentive may waste most of your effort. This is especially true when you are outside. How may times have you be on a tour, or with a group, where the trailing participants never caught up before the lesson was started?

Handouts.
If you hand something out, provide time for them to look at it first before you proceed. They will automatically be distracted by the commotion and will not be ready to learn.

Wait time.
As adults, we tend to dislike dead time in a lesson. It is necessary to give the student's time to think or you'll end up answering the question yourself. If you call on the first person raising their hand, learning will be hindered.

Be positive.
This is especially true when there is an incorrect response. Guide the student to a better guess by questioning! A flat no will cause the more timid student to abstain from even the slightest guess. If you make even one child feel foolish, it will permeate the lesson.

Discipline.
Know the class discipline procedures in advance and let the teacher handle problems whenever possible.

Enjoy yourself.
Above all have a good time. Life is too short to volunteer you time and be miserable. It doesn't mean you have to leave laughing. It just means you need to feel you've made a difference in the student's lives.

Typical Weather Topics at Grade Levels

(examples)

Kindergarten	**First/ Second**	**Third/Fourth**	**Fifth/Sixth**
Home stuff	school stuff	simple experiments	data collection
Days	kinds of seasons	climate	global process
Clothes	cycles	cause/effect	change
simple processes	seasons	airtemperature	precipitation
water	states of matter	heating/cooling	forecasting
hot cold	simple instruments	instrumentation	record keeping
play	Day/night	agriculture effects	civilization
	sky Changes	matter/energy	evaporation
	observation	water cycle	condensation
		physical properties	pollution
			equilibrium
			model/theory

Thinking and Learning Characteristics of Children

	Early Elementary K-2	Intermediate 3-5	middle school 6-8
thinking---			
	•manipulates objects	•concepts & objects	•hypothesizes
	•believes everything	•can classify	•can conceptualize
	•event oriented	•can induce	•can relate causes
	•sees parts, not whole	•begins to generalize	•relates principles
		•problem solves	•systematic
		•fact oriented	•relates probability
		•sorts/multiplies	•evaluates
Learning----			
	•Is adventurous	•understands rules	•is emotional
	•curious	•groups well	•easily bored
	•energetic	•social	•challenges authority
	•likes to please	•fairness important	•interested in opposite sex
		•avoids opposite sex	
	•impulsive	•self motivated	•likes small group
	•"me" centered	•independent learner	•vulnerable ego
	•loves praise	•perfectionist	•self conscious
	•attention span-10-15 min.	• 20-30 min.	•30-40 min.

The idea for this publication came from an NSF project developed by the North Carolina Museum of Life and Science. I gratefully acknowledge their earlier work. In addition, I would like to acknowledge the AMS's Project Atmosphere for their support and encouragement in fostering weather education. I would also like to thank Ms. Faye McCollum for her editorial assistance.

P1.13

WEATHER
An Interdisciplinary Approach

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1. INTRODUCTION

Reading, 'riting, 'rithemetic - these were once thought to be the only subject matter necessary for a successful elementary classroom. The focus in today's classroom is no longer just the three R's, but three R's and a S. Is this heresy? What is the "S"? Science is the obvious choice for an important addition to the elementary classroom. Even though the traditional textbook and a small amount of hands-on science has been in the schools for a long period of time, the focus on an integrated approach to teaching science along with reading, math, and language arts is becoming an important part of curriculum revision on the elementary level.

A grant through the National Science Foundation to the Arkansas Systemic Initiative has allowed the Department of Higher Education to address the needs of the science teachers in our state. The grant addresses the issues of curriculum reform, lack of suitable equipment, and the insecurities about content in the areas of reading, math, and science.

The Arkansas K-4 Crusade is the title of the initiative that began last spring in the classrooms of several universities around our state. Reading strategies,the use of manipulatives in mathematics, and the use of hands-on science activities were stressed in the thirty modules developed for the Crusade. Modules included topics as follows:

* Conceptual overview of literacy development
* Reading, writing, mathematics comprehension
* Thematic planning/curriculum integration
* Assessment strategies/portfolios
* Number sense
* Measurement and Shapes
* Properties of objects/classifying, sorting
* Ecology, Environmental Science, Space
* Electricity
* Light and sound
* Solar system
* Simple machines
* Geology
* Weather

2. THE WEATHER MODULE

2.1 *The Calendar*

Since weather is an ongoing process that should be observed every day, a weather calendar can and should become a focus of data collection for the students each day in class. This type of calendar can be made on rolled white butcher paper and placed in a very strategic position for the students to record observation and data as they enter the classroom. A group or pair of students may be given the assignment of recording the information about the events on the calendar. This could be a project carried on throughout the year. The calendar might contain the following data:

* Date
* Morning and afternoon temperature, inside and outside
* Morning and afternoon wind speed and direction
* Cloud shapes and types
* Precipitation in centimeters and inches
* Total precipitation for the year
* Moon phases
* Some extra scientific observation
* Some classroom or school activity for the day

Assignments for acquiring this data may be done in various ways. A group of students may be responsible for collecting this data each day and delivering the data to other class members for recording in their journals, and then this responsibility be rotated among student groups throughout the year. Students can also sign in on the calendar each day by answering a question, recognizing a weather symbol, or making an observation about a particular weather phenomena. This type of calendar does not have to be reserved just for a weather unit but can be used throughout the year for several different types of data collection activities. Learning to read charts in the newspaper can become a very important skill to complete the information for the daily classroom weather calendar.

Any weather event which takes place during

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the year should be recorded on the calendar. Newspaper articles could be the springboard for any other writing activities done about weather. Comparison of weather events around the country could be noted on the calendar since most newspapers have weather data from around the country.
(The weather calendar can be rolled up and stored each month, and other activities can be done with the data during the year.)

2.2 *Weather Instruments*

One of the first and most important instruments for a students to learn about is the thermometer. A simple thermometer with the Fahrenheit scale on one side and the Celsius on the other can be made with index weight paper and a red strip to simulate the liquid. The strip can be moved up and down the scale and readings practiced and recorded. Taking data from an instrument and organizing it in a way that the students can study the information can become a very important skill. Younger children can learn how to dress "Weather Bear" with the appropriate clothing as the temperature begins to drop.

Another simple instrument which can be built to make classroom observations is a wind vane. Compass directions become a very important fact when determining wind direction. Students are not often aware of cardinal directions in their environment. A change in wind direction during the day often means that a front has passed through the area, and that the weather may be changing. Predictions can be made by the students, and comparisons from previous weather observations can be made.

A simple anemometer can be built, and the wind speed can be determined by the students. This is a little more difficult to do and may only be done by the older students. This also applies to making a barometer, and observing the changes which takes place on the gauge built for this type of data collection. Students need to understand how high and low pressure readings are effected by frontal passage and affect the development of storms. Data from an anemometer and barometer may be difficult for the younger students to calculate and correlate to other weather changes.

2.3 *The Water Cycle*

Underlying most all weather concepts, especially precipitation and clouds, is the water cycle. This is usually one of the most difficult, yet most frequently taught, science concepts. Students often fail to realize what part the water cycle plays in the development of clouds. Even though they know that cloud types and precipitation are related there seems to be a link missing when these same students try to explain the water cycle. A non-traditional way to have a student to demonstrate his understanding of the water cycle would be to have the student write a story from the point of view of a drop of water, creating a "waterdrop adventure."

Students can also make a cloud in a bottle. This activity can be done in various ways, but the "Cloud in a Bottle" in the Project Atmosphere Cloud module is an easy way to produce a cloud.

Other writing exercises such as pyramid stories, circle stories, poetry, and haiku can be used as alternate assessment strategies for a weather unit. Younger children can construct a cloud book and write sentences to explain cloud types and location.

2.4 *Seasons*

The study of seasons during a weather unit provides an opportunity to correlate seasonal change with weather changes. Students still have misconceptions regarding the position of the sun and earth during the summer and winter solstices and the spring and fall equinox.

3. LITERATURE

Literature for all grade levels with references to weather is easy to locate. References to seasonal change, storms, hurricanes, different weather phenomena, and precipitation can be found in most any book. Informational type books can also be found on various reading levels. Big books as well as pre-primers can be found and used in classrooms ranging from kindergarten to sixth grade. Weather can be a basis for many different types of writing activities. Everyone can enjoy the mysteries and wonders of weather.

4. MATHEMATICS

Weather is the perfect subject for data collection. Students can organize temperature data into various types of graphs and charts. Comparing and analyzing data are very important skills for math and science. Using these types of skills in real life situations can show students how beneficial understanding can be for them in the future.

P1.14

ILLINOIS CLIMATE NETWORK EDUCATIONAL OUTREACH ACTIVITIES

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1. INTRODUCTION

Automation of the Illinois Climate Network (ICN) was initiated in 1988, with the last of nineteen stations added to the network in September of 1991. Hourly and daily summary data elements measured at the ICN stations include air temperature, relative humidity, solar radiation, wind speed and direction, barometric pressure, rainfall and soil temperatures at 10 and 20 centimeter depths. ICN staff are continually looking for new ways to use and distribute ICN data. Data are distributed on a regular basis to the agricultural community throughout the state of Illinois, particularly during the growing season (April-October). The University of Illinois Cooperative Extension Service and School of Agriculture use ICN data for their various newsletters, field days and research studies. Farmers and agribusinesses utilize ICN data to help schedule irrigation, field work and pesticide applications. Field agents from the Illinois Department of Agriculture have also made extensive use of ICN wind data to help document pesticide drift complaints. ICN data have also been used by our staff for presentations at Agronomy field days and teleconference weather briefings. Another potentially significant use for ICN data is in education and we have begun efforts during the past several years to encourage this use. This paper describes the educational outreach activities we have been involved in and are planning for the future.

2. EDUCATIONAL OUTREACH ACTIVITIES

2.1 *Site tours and workshops*

One form of educational outreach we have employed is conducting ICN site tours and workshops. Several local school groups have visited the Illinois State Water Survey Research Center and toured the Champaign ICN site. The 10 meter weather tower, instruments, data logger that records the hourly and daily measurements, and computer that downloads and processes ICN data are readily accessible for a close-up, hands-on look at how the ICN works. Workshops have provided an overview of the ICN and involved attendees in hands-on use of the data collected. We presented a workshop during the Illinois Geographical Society (IGS) Annual Meeting at the Illinois State Water Survey in April 1994. The IGS includes a mix of teaching and non-teaching geographers at all levels in education, government and the private sector. We have also staffed booths at the University of Illinois College of Agriculture Open House and National Chemistry Week Open House that are held each year to promote agriculture and science to students.

2.2 *Classroom exercises*

Several instructors from university, high school and grade school classrooms have requested ICN data for special classroom exercises. One teacher used several years of daily maximum and minimum temperature data to introduce his students to basic statistical principles (computation of means, medians, standard deviations, etc.). Another use of temperature data is in degree day analyses. Degree days are used to determine the accumulated effect of temperature on some quantity, such as fuel consumption (heating and cooling degree days) or plant growth (growing degree days). Degree days are calculated by determining the departure of the average daily temperature (maximum plus minimum divided by 2) from a given standard (typically 65°F for heating and cooling degree days and 50°F for growing degree days). We have prepared several degree day exercises for use at workshops and in the classroom.

In the spring of 1993 the ICN was used as a backdrop for what became known as the Illinois School Children's

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Atmospheric Network (ISCAN) (Schmalbeck and Peppler, 1994; Schmalbeck et al., 1994). A curriculum supplement focusing on water in the environment was tested in two middle school classrooms in Urbana-Champaign, Illinois. It was taught by University of Illinois student teachers who received assistance from University professors and ICN staff. The ICN was used as a model for how a data collection system can be designed, including all of the pitfalls one can encounter during such an endeavor. The curriculum included hands-on demonstrations, computer simulations, simple lab techniques and data collection through a small network of middle school volunteers. One of the main byproducts of this work was the establishment of a well-defined role for scientists in science education.

2.3 *Computerized data access*

For ICN data to be useful for educational outreach, they need to be easily and affordably accessible. With the proliferation of personal computers, computerized access to data is becoming the preferred access method. A personal computer, modem and communications software are generally all that are needed to access most computer databases. Since 1990, ICN data have been available on the Midwestern Climate Center's subscription-based dial-up computer system, MICIS (Kunkel et al., 1990). Beginning sometime during the fall of 1994 we will also upload processed data to the University of Illinois' Department of Atmospheric Sciences "UI Weather Machine" computer. This weather database can be accessed over the Internet using the "Gopher"[1] software communications protocol. ICN analyses are then available for access by anyone in Illinois or the world who has direct or phone/modem access to the Internet and Gopher software. A third type of computer access to ICN data that we have explored is Prairienet, a community-oriented computing system implemented by a group of volunteers in east central Illinois. It is part of a national organization of community networks known as "Free-nets". The primary purpose of Prairienet is to provide computing and communications facilities to those segments of the population who currently lack them but may have much to gain from their use, including K-12 students and teachers.

3. FUTURE PLANS

We are working on a preproposal to the National Science Foundation's Program for Instructional Material Development and Dissemination that would include funding for the development of a computerized atlas of ICN data and curriculum development to accompany it. Further automation of ICN data retrieval and processing will speed up data turnaround and improve the timeliness of data delivery. As funding becomes available, we would also like to develop our own dial-up system which will make hourly ICN data available in real-time. Further, we would like to actively initiate contact with local and regional schools and let them know that we are willing to help conduct workshops and tours and to assist in materials development to enhance their classroom explorations of weather topics.

4. SUMMARY

The potential educational benefits from ICN data and informational products are many. The ICN database extends back to the late 1980's, is readily accessible and should be used. We will continue to look for new and innovative ways to improve and enhance the quality of our information products and educational outreach.

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[1] Gopher is a public domain information delivery system developed at the University of Minnesota.

P1.15 THE FLORIDA STATEWIDE WEATHER NETWORK

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1. Introduction

The National Weather Service (NWS) Office at Melbourne, Florida (MLB) has for some time collected "cooperative observer" reports for the state of Florida and reported a summary of these observations on a daily basis. The Florida Statewide Weather Network (FSWN) is now supplementing this observation network with volunteers from schools throughout the state. Data reporting is via a toll-free touch-tone phone system and daily reports are sent to teachers via the Florida Information Resource Network (FIRN). Teachers and students have daily access to the cooperative observer data and FSWN data in the form that it appears for use by the general public and news media, and also receive the data in a form that is usable in spreadsheets for graphical and statistical applications (forthcoming in Fall 1994).

By fall of 1994, over 75 schools will be equipped with inexpensive maximum/minimum thermometers and wedge-type rain gauges. These observations are typically taken by sixth graders at schools across the state. Among the many types of uses for these data are in daily weather briefings conducted by the schools over their public address systems, and for data analysis work in their mathematics and science classes. Teachers and students have received detailed instructions for siting of weather instruments, use of topographic charts to understand and report their geographic location to the network, analysis of time series and spatial data, and comparitive studies using other forms of meteorological information available on television weathercasts, the newspaper, and weather information servers, where hourly reports from official observing stations and satellite and radar images are available. They also begin to gain an appreciation for the relationship between their own observations (sky conditions, weather conditions, etc.) and temperature and precipitation, for example, the relationship between diurnal temperature range and precipitation. Seasonal and annual patterns are established in those schools which participate year-round.

Students compare their observations with the nearest cooperative observer locations and try to explain the differences in terms of human error, instrument error, and/or from a meteorological basis. Many teachers report the creation of bulletin boards centering on weather information which are updated every day, in spite of the fact that weather may be a unit covered in only a six or eight week session. We do not advocate here the teaching of meteorology to the exclusion of other earth sciences in a traditional middle or high school earth science course. However, meteorological data such as is available from the FSWN provides information to schools to use in any type of data analysis course during the course of the entire academic year. National educational objectives are increasingly stressing an individual students' ability to understand simple to complex interrelationships between various data as an important life skill. This network of data, available free to over 3,000 teachers in Florida by electronic messaging and group conferencing on FIRN, and to other users on the NOAA/NWS Family of Services (FOS), will ultimately provide a useful framework for the use of meteorological data, widely available free of charge to educators, to meet such objectives.

2. FSWN Data Access Path

Students collect their data in the morning and log them onto record sheets according to instructions given to them by their teacher. By 10 AM each day, NWS MLB has completed its job of collating the observations from the Florida cooperative observers, and the toll-free telephone data logger becomes available for use by FSWN participants. The data are called in by the students using a simple instruction sheet provided by the project staff. The window of opportunity for dial-in is from 10 AM to 1:30 PM each day. Sites can easily correct their mistakes. At 1:30 each day, the MLB computer shuts down new data entry, and processes the data for formatting of the public message.

The typical NWS collective report for cooperative observer stations is shown in Table 1 and an example of FSWN data is shown in Table 2, in the formats received by the teachers in their electronic mail boxes. On FOS, the header is SRUE10 KMLB, the same as is used for the cooperative observer data collective which comes out earlier in the day. At FSU Meteorology, as the message comes into our data ingestor, the entire report is automatically forwarded to all the teachers and their classroom FIRN accounts; receipt is usually by 2:30 PM each day. This timetable is not necessarily optimum for same-day use, but works well for classroom or special project use.

Using cooperative data from Alabama and Georgia, we also objectively analyze data each week to track shifts in wet/dry patterns and we are working to establish ways in which this product can be placed on the FSU Meteorology gopher and World-Wide Web home page for use by teachers. Products originate weekly in FOS messages from the National Weather Service office at Auburn, Alabama. Using GEMPAK (Bruehl 1994), these data are converted to parameters including weekly, 30 day, 60 day, and year-to-date precipiation totals and departures from normal. An example of a plot from this type of product is shown in Figure 1.

3. Curricula

The test for the project was conducted in 1992/93 using 25 sites. The typical response rate was 20-30% due to a variety of factors. In order to improve the response rate for this year, not only have we increased the amount of our training materials (through distribution lists on electronic mail and mail-outs to the teachers), we have also developed a set of curriculum materials and "modules" which can be used to develop FSWN data usage in the classroom. These curricula will be published by the Florida Department of Education during 1994/95 and include the following topics:

- Florida Geography
    - NWS Reporting Stations
    - FSWN Reporting Stations

- Universal Coordinated Time

- Instrument Shelters
    - Color; Soil types; Instruments

- Temperature Scales
    - Fahrenheit; Celsius; Kelvin

- Graphs
    - Temperature
    - Rainfall

- Isotherm Analysis
    - Isoplething techniques

- Rain Gauges
    - Mounting and reading a rain gauge; Correlation of rainfall to satellite picture; Causes of precipitation

- Meteorograms and Time Series
    - Construction and interpretation

4. Goals

During 1994/95, participants will gain more familiarity with their instruments and many will build weather instrument shelters to improved the representativeness of their data. We will provide an alternative to the product listing shown in Table 2 to facilitate the inclusion of cooperative observer and FSWN data into spreadsheets so that teachers can create statistical and graphical summaries of their data.

FSU has recently begun mirroring the University of Michigan Weather Underground and their Blue Skies package (Samson et al. 1994). We will incorporate a similar interactive weather map in the future to facilitate the data entry and data display capabilities of FSWN.

Through the Florida EXPLORES! program (Ruscher et al. 1993; Ruscher et al. 1995; Kloesel et al. 1995), we have begun to establish a wide variety of educational resources and materials to teachers in elementary, middle, and high schools. An annotated bibliography has also been prepared (Ruscher and Kloesel 1994) which has been distributed to all FSWN schools.

Acknowledgements

This work would not have been possible without the support of Dan Smith, Scientific Services Director of the National Weather Service Southern Region, and Bart Hagemeyer, Meteorologist-in-Charge at MLB. Nikole Winstead, Faith Lans, Anil Rao, and Jeff Orrock have all assisted in various aspects of the developing phase of this project. The teachers and students who have participated are ultimately responsible for the success of this project and they are the ones who deserve the most thanks!

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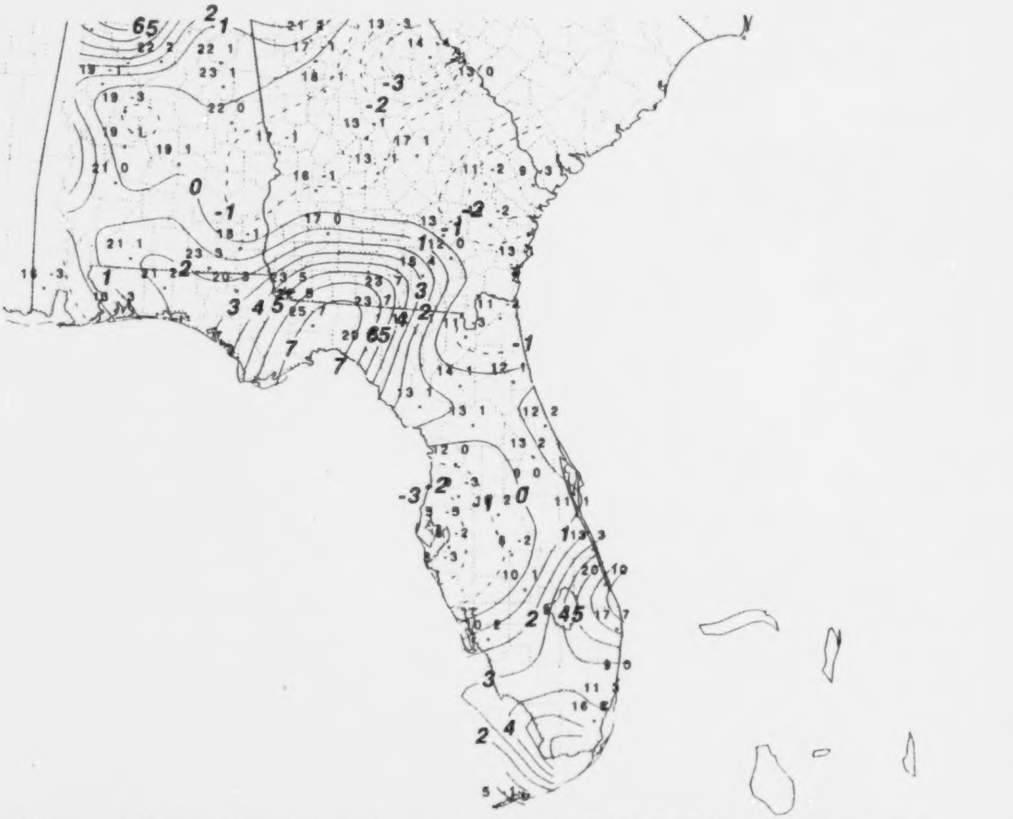

Figure 1. Analysis of precipitation (year-to-date, in inches) through 20 April 1994, using cooperative NWS station data from Alabama, Georgia, and Florida. Plotted are year-to-date rainfall (upper left) and departure from normal (upper right) for each station. Some data are not plotted to avoid overlap. Analysis produced using GEMPAK.

Table 1. Sample Cooperative Observer Report from NWS MLB

```
SRUE10 KMLB 011432
RRMMLB
FLORIDA SUPPLEMENTAL PRECIPITATION SUMMARY
NATIONAL WEATHER SERVICE MELBOURNE FL
1032 AM EDT THU SEP  1 1994

24 HOUR PRECIPITATION ENDING AT 8 AM EDT
TEMPERATURES ARE DAYTIME HIGHS AND NIGHTTIME LOWS

STATION           ID     PCPN  HI LO   STATION           ID     PCPN  HI LO

NORTH FLORIDA...

BAXTER            BAXF1  0.00          HASTINGS          HTGF1  0.00  95 69
BENTON-TAYLOR     BNTF1  0.22          HAVANA            HVNF1  0.00
BLOXHAM           BLXF1  0.42          JACKSONVILLE      JAX    0.00  94 72
CHIPLEY           CHPF1  0.00  93 69   JAY (MILTON)      MILF1  0.00  93 68
CRESTVIEW         CEW    0.00  92 68   LAKE CITY         LCTF1  0.00  92 [illegible]
DE FUNIAK SPR     DEFF1  0.00  92 70   LIVE OAK          LIVF1  0.00  93 69
DOWLING PARK      DOWF1  0.00          MARIANNA          MARF1  0.00  93 69
ELLAVILLE         ELLF1  0.22          MONTICELLO        MTCF1  0.00  90 69
ELLAVILLE-NOBLE   ELAF1  0.00          PENSACOLA         PNS    0.00  89 73
GAINESVILLE       GNV    0.00  89 70   QUINCY            QCYF1  0.00  93 68
GAINESVILLE AG    GNSF1  0.00  95 66   TALLAHASSEE       TLH    0.00  95 6[illegible]
GLEN ST. MARY     GSMF1  0.00  92 75   WOODRUFF          WDRF1  0.07

CENTRAL FLORIDA...and SOUTH FLORIDA omitted for the sake of brevity
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Table 2. Sample FSWN Observer Report from NWS MLB

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SRUE10 KMLB 041835
FLORIDA SUPPLEMENTAL PRECIPITATION SUMMARY
FLORIDA STATE UNIVERSITY METEOROLOGY DEPARTMENT TALLAHASSEE, FL
 230 PM EST THU MAR  4 1993

FLORIDA SCHOOLS PRECIPITATION AND TEMPERATURE SUMMARY
24 HOUR RAINFALL AND TEMPERATURE DATA ENDING AT 10AM THIS MORNING
TEMPERATURES ARE DAYTIME HIGHS AND NIGHTTIME LOWS

SCHOOL                ID      PRECIP   HIGH   LOW

HAVANA 5N             HAVAN     2.08     65    46
BRKSVL POWELL MIDDL   BROOK     0.90     87    38
KILLEARN LAKES        KILLK     2.08      M     M
LARGO SOUTHERN OAK    LRGSP     1.50     79    59
HOLLY NAVARRE SCL     NAVAR     0.30     63    50
NEW PT RICHY BAYONT   RICHY     0.59     80    58
PALATKA JENKINS MDL   PLTKA     0.80     82    59
SATELLITE BEACH SCL   SATEL     0.12     76    59
TALAHASEE GILCHRIST   TLHSE     0.50     82    44
VERO BCH MIDDL SEVN   VEROB     0.70     79    43
WAKULLA MIDDLE SCL    WAKUL     1.30     78    48
END  TEST  DATA/MLB
```

BEST COPY AVAILABLE

P1.16

TECHNOLOGY AND RESEARCH PARTNERSHIP: THE NEXT STEP IN METEOROLOGICAL INTERNSHIP PROGRAMS FOR HIGH SCHOOL STUDENTS

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1. INTRODUCTION

Pre-college science education is in the midst of unprecedented change in the United States. A wide variety of evaluative reports have been published that are critical of the traditional approaches to delivering science content, and that offer alternatives that emphasize the processes of science rather than rote memorization and cookbook experiments. A new approach being implemented at all levels is "authentic learning." In authentic learning, students learn science content most effectively in the context of solving real problems that pique their interest or may have an impact on their lives. The delivery of content is driven by a "need to know," as students unravel the many aspects of a real task.

High school teachers have long recognized that many students, even the best ones, lose their initiative during their senior year. At a time when young men and women could be synthesizing their knowledge in various subject areas to address real concerns, very little is offered them in the average curriculum. In an effort to bring authentic learning to the last year of a student's pre-college life, the Office for Instruction and Program Development of Montgomery County Public Schools, under the leadership of Dr. Joseph Villani (1994), is working with five high schools during the 1994-1995 school year to pilot the Technology and Research Partnership (TARP) program. Each school has autonomy to configure its TARP program independently, within broad guidelines, to meet its local community needs and tap the expertise of its faculty. Gaithersburg High School has elected to emphasize meteorological problem-solving.

2. GENERAL DESCRIPTION OF THE TARP PROGRAM

TARP is a designed to give high school seniors and exceptional juniors an opportunity to work on a team using current organizational and technology skills to solve an authentic problem in partnership with a community-based business, corporation, or agency. It is scheduled as a double-period class each day, with each participant earning one credit in advanced technology and one honors credit in science. The goal of this authentic problem-solving approach is to give students a vision of the applicability of academic learning, as well as giving them a chance to learn to work as a team and to solve both technical and interpersonal problems likely to be found in an authentic work situation.

At the core of the program are the development of the following specific competencies:

a. use of statistics in experimental analysis;
b. reading and writing technical articles;
c. using on-line data-bases and electronic libraries to do research; and
d. team planning, problem analysis, and quality performance.

Two new technological developments at Gaithersburg High School enhance the learning of these competencies. Access to the Internet is now a reality, bringing availability of electronic mail and menu-driven database searching of host computers all over the world. And Gaithersburg High School has been chosen as a recipient of Global Access technology, which will greatly increase the number of computers in the building to do Internet searches. These computers are to be networked throughout the building, providing access to CD-ROM databases in the media center at any time.

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The expected outcomes of the TARP Program include the following:

a. demonstrated competency in using a computer to search for information, analyze data, make predictions, and solve problems;
b. demonstrated competency in interpersonal skills necessary for effective membership on a working team; and
c. production of a formal cooperative research paper, to be presented to the community partner on at another suitable site.

3. THE TARP PROGRAM AS CONFIGURED AT GAITHERSBURG HIGH SCHOOL

The concept of cooperative research on authentic problems is not entirely new to Gaithersburg High School (GHS). Since 1989 an in-house internship program has been in place with an emphasis on meteorology and the processing and analysis of weather satellite images (Krayer, 1993). Since its inception, the in-house internship program has involved more than 25 students, some of whom have gone on to continue their education in science and engineering.

The TARP Program is the next step in the ongoing internship program at GHS. A partnership has been established with the National Weather Service Forecast Office (NWSFO) in Sterling, Virginia, to conduct research which is of value to the meteorologists on duty there. This year the primary topic of investigation is the detailed structure of the urban heat island created by the Washington, DC, metropolitan area. The TARP student team is planning to use data from several networks of school-based weather stations associated with local television stations, as well as observations from cooperative observers, to search for patterns in overnight low temperatures and their relationship to synoptic conditions over the area, topography, and local land use. In addition to National Weather Service involvement, several local corporations are lending support to help the students in areas such as statistical analysis, quality assurance, time management, and team building skills.

During the first nine weeks the students are introduced to the use of technology to carry on cooperative research. They are also exposed for the first time to the writing of research proposals and final reports. Specifically, small groups of students

a. select a general area of research interest (e.g. a weather pattern or event, satellite image processing, instrument design and testing);
b. respond to a "mini-RFP" with a proposal stating the problem they intend to solve, their research methods, software and/or data services they plan to use, how they plan to incorporate statistics, and the form of their final presentation;
c. conduct a background literature search using electronic databases;
d. proceed with the research, learning how to use equipment and software as the need arises;
e. write a report of their investigations, using proper technical writing skills; and
f. present their research to their peers and interested faculty.

Throughout the process a faculty advisory team consisting of the TARP coordinator, technology education coordinator, and media specialist are available to students who need specific instruction. Additionally, several professionals from community businesses answer technical questions either during visits to the school or by electronic mail.

After the small-group presentations are completed, the Sterling forecast office and TARP advisory team collaborate to issue the principal RFP announcement. The following outline details the expectations set before the students (Montgomery County Public Schools, 1994):

a. Preliminary Proposal
    1) a short abstract that briefly describes the problem to be solved;
    2) the plan for solving the problem; and
    3) a time line with anticipated checkpoints.

b. Full Proposal
    1) project narrative, including a specific problem description, goals and objectives, and project characteristics;
    2) list of resource needs, including information, equipment, and supplies;
    3) anticipated products resulting from the research;

4) project calendar, an expanded time line showing logical sequencing of events and major milestones;
5) project staff descriptions and responsibilities;
6) description of past research in the field, and how past results are reflected in the project design; and
7) an evaluation plan assessing the effectiveness of the research.

The preparation, review, and revision of the preliminary and full proposal documents is scheduled to be completed at the end of the second grading period, in mid-January.

The data collection and analysis moves forward at the beginning of the second semester. Additional background research accompanies the experimental phase. The team completes the work sometime during the month of April, at which time the students prepare their final presentation to an audience including meteorologists at NWSFO Sterling. The presenters are encouraged to use presentation graphics or a multimedia approach.

At the end of the school year all research papers are compiled into an Operations Report, a technical journal of the accomplishments of the TARP student researchers (Krayer, et al, 1994). Copies of the report are given to each student and filed in the school's media center for future reference.

4. PROGRAM MANAGEMENT CONCERNS

A new initiative with the scope of the TARP program presents challenges to the coordinator. Since many students work simultaneously on a variety of subtasks, the coordinator's availability is often divided among several problems in need of solution. In addition, attention must be given to such concerns as organizing materials and data, raising money and purchasing equipment, and public relations. In keeping with the general objectives of the program, students are asked to assume the following responsibilities:

a. business manager - assists in keeping financial records, and helps to manage proposals for grant funding;
b. laboratory administrator - keeps the work area organized, and develops a logical system to archive hard copy and floppy disks;
c. student media specialist - works with the staff media specialist on the advisory team, and keeps a video and photographic record of TARP student work;
d. public relations coordinator - keeps student and community newspapers informed, and looks for ways to promote the program.

The coordinator is also assisted by two other faculty members, the technology education resource teacher and a media specialist, to form the advisory team. They provide invaluable insight into the progress of students in the program, and are able to assist in specialized areas such as engineering of experimental hardware or accessing on-line databases.

5. STUDENT AND PROGRAM EVALUATION

Three methods have been established for student assessment in the TARP program. Every other week all students fill out an evaluation form, on which they list the number of hours they worked. Students also evaluate their own performance in areas such as punctuality, efficiency, learning growth, and human relations skills, and are encouraged to provide feedback to the advisory team concerning problems in need of attention. Second, all participants must keep a daily journal of their activities. Finally, students establish files, or portfolios, which they fill with evidence of their learning. Portfolios may contain printouts from on-line databases, computer programs, processed satellite images or any other document that demonstrates personal achievement. At the end of each grading period each student is scheduled for a formal conference with the TARP coordinator, where all performance assessment criteria are reviewed. Weight is also given to the performance of research groups.

The advisory team plans frequent meetings to address student concerns and evaluate the progress of the TARP program. The team also considers input from professionals who partner with the students.

6. ASSURING PROGRAM CONTINUITY

The TARP program differs from an authentic research establishment in one important way: it loses most of its employees every year. The recruitment of qualified, motivated young men and women for the following school year is critical to the continued success of the program. The coordinator plans to begin recruiting students in January, about a month before registration. Later in the spring, transition meetings are scheduled so that present participants can introduce their successors to the overall TARP plan. Even though the main research topics may be very different in the 1995-1996 school year, the basic principles of TARP remain constant.

7. CONCLUSION

The Technology and Research Partnership Program is an ambitious attempt to bring authentic learning to older high school students who are making important career decisions. This pilot project is not yet through its first year, but the preliminary evaluation seems promising. Through collaboration with the local National Weather Service Forecast Office, a complex research problem is being addressed. The results of this project hopefully will be of value to the meteorologists who may use them. However valuable these results may prove to be, the processes of research, experimentation, technical reading and writing, and group cooperation will be of immense value to the students as they move on to higher education.

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P1.17

ESTABLISHING PARTNERSHIPS BETWEEN BUSINESSES AND SCHOOLS

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Education is at the crossroads in many regards. In the coming years parents, the community, and businesses may be major components of the cornerstones in education. I have found that promising ideas and enthusiasm open the door for businesses to get involved in supporting school projects which meet their philosophies and guidelines. Small ideas can blossom into larger ideas that can be significant in bringing together parents, students, businesses, and teachers.

My presentation is about partnerships that I have found to be successful and are available to you.

The easiest place to begin is by establishing a partnership with a local television studio. A phone call to the meteorologist is all it takes. Studios are willing to give tours or better yet, follow up a tour with the opportunity to sit in on a live news telecast. What a thrill this was for the parents, the students, and myself. We were able to talk to the newscasters when videotaped segments were used. When the telecast was over, the students were allowed to see how the projection of the weather maps was done. They were allowed to role play being meteorologists using the "green screen" and monitors. If possible, I recommend you learn the color of the screen in advance of the tour. Have students wear clothing that matches that color. They will be amazed to find they are nearly invisible on the screen. None of this would have been possible if I didn't have the nerve to ask if sitting in on a live telecast was possible. The studio won't offer to have 20 people sit in on a live telecast, unless you ask. And we were invited back. This service is a great public relations for the meteorologist, the studio, and perhaps most importantly the ratings. The meteorologist comes to our school to do presentations and provides my class with data sheets stating last year's highs and lows, normal highs and lows, year of record highs and lows, precipitation, sunrise and sunset times, and many other weather related data. Invite your meteorologist to your school and establish a partnership with the TV station.

Partnerships with funding sources may also be available in your state. In Iowa, the Iowa Energy Center and the Iowa Science Foundation provide funds for projects involving energy and science education. High Efficiency Lighting Systems for Schools is a project with a component quantifying the amount of toxic pollutants prevented from being released into the atmosphere. These pollutants include carbon dioxide, sulfur dioxide, and nitric oxides. This material provides an excellent lead in to the study of global warming, acid rain, and smog.

Partnerships with businesses require more energy but the results are very rewarding. Partnerships with electric utility companies can easily be established. Creative ideas and enthusiasm meeting the businesses' philosophies and guidelines are important elements for a successful partnership. Maintaining open lines of communication will enhance the success of your project. I can't stress enough the importance of getting the partners involved and working together as a team to develop your project.

In Iowa 97% of the dollars needed for energy production goes out of our state. To help decrease this amount, in 1990 the Iowa legislature passed a state law which required utility companies to promote energy efficient programs. Iowa utility companies are required to provide certain benefits to their customers. Many Iowa utilities provide their customers with efficient shower heads, sink aerators, fluorescent lamps, water heater blankets, pipe insulation, and several other devices. In addition, our utilities pay a technician to install the devices. Why not get the utilities to give your class all the devices and have your class do a research project on the savings of water and energy between the devices presently in their homes and the efficient devices that will be provided? Your students can develop their own testing methods between the plumbing fixtures in their homes and the energy efficient devices. Let your students immerse themselves in the scientific method of discovery by doing field based research that is inquiry driven.

But first who do you contact? In my case it was the marketing analyst for Iowa-Illinois Gas and Electric, the senior marketing engineer for Iowa Electric Southern, and the member services supervisor for Linn County REC. These people were very willing to help. They provided our school with "check meters" to measure the energy used by large appliances and "low wattage meters" to measure the energy used by light bulbs, fluorescent lamps, and engine block heaters. A demand site service company provided many of the water and energy efficient devices at cost. This enabled the middle school students to be involved in our project entitled "Student Research: An Investment in Our Future". Again, I can't overemphasize the importance of having an idea that meets the guidelines and philosophies of utilities and businesses. In this case their goals were to save the customer money, to save the utility company money by decreasing peak loads, to keep the utility company rates down by not having to make additions to the power plant and to install gas lines, to save our fossil fuels, and, perhaps most important, to help our environment by decreasing pollution emissions.

I have found these business partnerships to be very rewarding. Students learned 1) about energy and water conservation; 2) pollutants that can be decreased; and 3) content terminology by doing field based research that was process oriented. Parents were directly involved by assisting their children in measurements and in verifying the data that was collected. The students learned and came to appreciate the wonders of computers for developing spreadsheets and a database. The community was involved by having students make presentations about our project to the City Council, the School Board, and the EPA in Washington, D.C. The school was involved through the first middle school wide interdisciplinary unit that cut across the curricula. Publicity about our project was provided by area newspapers and local TV stations. This involvement resulted in the utilities, the demand site service company, and West Branch Middle School science classes receiving numerous awards including the President's Environmental Youth Award and Busch Garden Sea World A Pledge and A Promise Environmental Award.

Many Iowa utility companies also provide an assortment of Energy Education Resource Programs. A catalog detailing the services is available. Tours are given and guest speakers visit the schools. The kits include activities and literature. Computer software, tapes, films, and filmstrips are on loan. I strongly recommend establishing a partnership with your local utility.

The last partnership I will discuss involved the federal government. Putting together a successful partnership involved many people throughout the United States. In the end, the partnership was very rewarding because of the great experiences that were provided to the teachers. Again, a small idea grew to become reality. The keys to ensuring success are: asking people for help, informing them about your idea, and getting information of where to go for additional help. We all need assurances that our ideas will be successful. In my case, Dr. Ira Geer and Ms. Ellie Snyder provided the assistance I needed. Because of their involvement, an 8 hour short course was presented at the NSTA National Science Convention in Kansas City. Twenty-four teachers were able to use the National Severe Storms Forecasting Center and the National Weather Service training Center to learn more about how weather forecasting is done. Dr. Joe Schaefer, Mr. Rich McNulty, Mr. Pete Chaston, Mr. Joel Wertman, Mr. Jerry Griffith, and Mr. John Jerboe went beyond what was asked. The participants were involved in a hands-on radar simulation and downloaded and printed current weather maps from their states using AFOS. There was no charge for using the facilities. The teaching of the radar and AFOS was done by the staff at the National Weather Service Training Center. Two Project Atmosphere presentations were done by Atmospheric Education Resource Agents, Ms. Pat Warthan and Ms. Kathy Murphy. Dr. Schaefer, director of National Weather Service Training Center (NWSTC) commented, "This type of cooperative venture between the local schools and the federal government (NWSTC) is a classic example of a win-win situation." The ultimate compliment was made when Dr. Schaefer asked me to set-up this workshop again. Dr. Schaefer, the National Weather Service Training Center staff, and the Project Atmosphere AERA agents all worked together to form a successful partnership.

Unfortunately, facilities such as the National Weather Service Training Center are limited to teachers in that area. Facilities such as training center exist throughout the United States. The directors are willing to have teachers use their resources. Search and find out what is nearby, then develop a creative idea which meets their philosophies and guidelines.

Weather Service Forecast Offices are also located in many states. Many of these centers are replacing their old weather stations with computerized systems. Weather stations complete with psychrometers, barometers, hygrometers, and a rain gauge can be obtained on loan from them. Your students will be more involved in doing real life weather observations. As volunteer weather observers they will become a part of the Cooperative Observers Program.

These are some examples of how small ideas can become a reality. Area businesses want to be more involved with the community and the school. Look around and explore the possibility of establishing partnerships with your school.

P1.18 Project Atmosphere Gives Teachers a New Look at the Water Cycle

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In most grade levels the topic of weather starts with an introduction of the water cycle. In this introduction the teacher proceeds to illustrate or point out chart models of the water cycle. A problem arises with this presentation in that the student soon attaches little value to the concept because it is only something that exists on a flat piece of paper warranting little to no importance to the daily life of anyone. At this stage Project Atmosphere is helping to improve the presentation of this topic through its module entitled *Water Vapor and the Water Cycle.*

In the module teachers are provided basic understandings of the substance of water, the water cycle, water vapor, water vapor observation, saturation and precipitation. Water vapor observation is a new tool for the classroom teacher with the availability of current satellite imagery. Because of the newness of this tool, Project Atmosphere is explaining to teachers what they are observing and why, so they would be better able to teach their students. You see these students see the current satellite imagery whether on TV or in newspapers with little to no explanation to what they are seeing and why.

It is exciting to see the "light come on" when you tell teachers, as they look at the satellite images, that they are looking at the water cycle in motion. The break from the traditional flat paper model to the real life image is rewarding. The presentation of this module includes a video tape entitled, *Water Vapor: The Unseen Weather*. In this tape, an explanation is given in the use and meaning of satellite water vapor imagery. The video compares this weather observing product to more familiar infrared images seen daily on TV.

Examples of water vapor imagery of historical importance are highlighted in the video which brings a high human interest level in focus. These significant weather events include the following: The Blizzard of '93 which brought widespread winter conditions to the East Coast resulting in 250 deaths; the flash flooding in Texas during September 13-16, 1991, which was the result of flood producing thunderstorm; flash flooding in Kentucky during July 24-26, 1992, as presented in both full-disc and North American sector loops of water vapor circulation, flooding and tornadoes in the southern plains during May 8-9, 1993 which includes the disastrous floods near Oklahoma City, Oklahoma, and the deadly tornado damage near Dallas, Texas which resulted from serve thunderstorms. Hurricane Hugo during September 21-22, 1989, and Hurricane Andrew during August 23-27, 1992, are also shown.

The weather cycle is usually presented in a very calm cycle of events, yet in the examples above one can quickly conclude that usually it can be just the opposite. Students' attention and interest level is

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P1.19 PROJECT WEATHERWATCH: A COOPERATIVE METEOROLOGICAL EFFORT BETWEEN PROJECT ATMOSPHERE AND THE GREATER NEWARK CONSERVANCY

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1. INTRODUCTION

Project Weatherwatch is a developmental program between teachers of one of New Jersey's largest cities and Lyndhurst, a near-by suburban/urban school district. At the inception of Project Weatherwatch, five Newark schools were solicited by the Greater Newark Conservancy a non-profit, private group whose sole purpose is to bring enrichment activities associated with weather and environmental issues to Newark teachers. Prior to the weather program, the Conservancy pioneered a garden project throughout the city. Richard Lees, a Project Atmosphere AERA located near Newark, NJ, was contacted to provide insight, resources and training for the original Newark participants. these teachers were from both public and private schools.

2. BACKGROUND

The Newark, New Jersey, School District, with approximately 48,000 students in 1993-94, is the largest in the state. Its average per pupil expenditure is now greater than $10,700 per pupil. This is well above the state average. "-----The Sunday Star Ledger, July 31, 1994.

The Newark School System is also the largest of the state identified "special needs" districts, which is the descriptive term for a district that has an overwhelming number of students from low-income families. Additionally, these students represent racial and ethnic minorities with nine percent white and one percent Asian. "-----, The Sunday Star Ledger, July 31, 1994.

3. THE PROBLEM

"Report on Newark system reveals disturbing facts," "The Sunday Star Ledger, July 31, 1994, "Newark Schools cry out for improvement," "The Sunday Star Ledger, August 21, 1994, "Target: Newark: Sate set for takeover of failing school district, " -Tuohy, 1994, "Newark schools facing their final warning notice," "Braun, 1994, are a few of the recent headlines that reveal that the Newark School District is not meeting the needs of its students.

A State Department Education report identifies numerous deficiencies throughout the educational effort of the city. Although many serious problems are stated as administrative, critical issues found in the classroom were most stunning. "-----, The Sunday Star Ledger, August 28, 1994. The majority of pupils who remain in Newark's schools are in danger of leaving high school without a diploma because of the inability of those students to pass the state-mandated graduation test known as the HSPT11.

One aspect revealed in the visits of state officials was that "instruction was and is unchallenging. Children were not being encouraged to generate their own ideas, to collaborate in problem solving activities, to write in class, to read widely, or to use skills and facts in context. Where science teaching does occur, students are rarely given "hands-on" experience. "-----, The Sunday Star Ledger, July 31, 1994.

4. THE GREATER NEWARK CONSERVANCY AND PROJECT ATMOSPHERE

The Greater Newark Conservancy works to improve the quality of life in the greater Newark area. It has established a Youth Education Program to promote environmental awareness and action. The GNC applied for and gained funding for "Project Weatherwatch", a program for both public and private school staff to gain personal hands-on experience with meteorologic phenomena. Hopefully teachers will gain strategies for improving their students' critical thinking , problem-solving and decision-making skills.

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A letter form the Greater Newark Conservancy was received by Lees, a NJ AERA. The communication stated "I would like to enlist your help in the GNC effort to make things better in the Newark schools... ." *Hadley, 1993. Thus, Project Atmosphere became an integral part of the movement. Through mutual cooperation between the GNC and Project Atmosphere , the Newark teachers were provided with much-needed science (weather) equipment and were exposed to teacher training that introduced effective teaching and learning methods.

Project Atmosphere modules such as Clouds, Hazardous Weather, and Water Vapor: The Unseen Weatheralong with Look Up! wrap-arounds were used to provide the basis for training workshops. These workshops were held in one of New Jersey's premier environmental centers located in the Hackensack Meadowlands. Here one also finds the world's first garbage museum!

"By day's end, teachers were discussing fronts and dew points, highs and lows, and even making clouds appear in soda bottles." *-----, City Bloom, Spring, 1994.

5. PLANS

Workshops, visits and training will take place during the 1994-95 school term. Expansion to five additional Newark Schools is planned. Furthermore, the nearby suburban/urban school district of Lyndhurst is adopting a similar program with sister schools between communities as a result.

Project Atmosphere materials will again serve as catalysts for action.

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P1.20

LIGHTNING HAZARD EDUCATION

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1. INTRODUCTION

This paper assesses misconceptions that students, science teachers, and the general public have of the lightning hazard. While most of the available information in school texts and pamphlets is correct, it is not clearly presented and the hazard remains confusing to most people. A person's perception of the lightning hazard appears to be derived from what was learned during school years.

2. PROACTIVE PLANNING

Not enough emphasis has been placed on the ***proactive*** ability to recognize a lightning hazard. Instead, most literature and training materials treat the ***reactive*** mode. This approach emphasizes the posture to take when a person is caught by surprise in the open (i.e., it is too late for precautions) by a thunderstorm when the lightning threat is at its greatest.

Questions from the public or media often start with issues similar to the following ideas:

- "Is it better to wear rubber-soled shoes than metal cleats on the golf course?"
- "Should I move away from my metal bicycle because it's more likely to be hit?"

We delay answering these types of questions at the start of a question and answer period. Rather, we concentrate on the primary issue:

"Why be on a golf course or riding a bike during a significant lightning threat in the first place?"

When the discussion starts this way, there is an opportunity to explain a proactive approach to lightning safety that emphasizes advance planning. A complete explanation involves a sequence of decisions on a time scale from days to seconds. For an all-day hike, consider the following actions according to time sequence:

- **Days before activity**
  1. Be aware of the possibility of storms that may form in the area and at the time of an activity. Listen to weather broadcasts by the media and NOAA Weather Radio for general outlooks.
  2. Decide on rules to stop the activity, and where to take shelter.
- **Day of activity**
  1. Have a plan at all times during the hike for where to take shelter if lightning moves toward your location.
  2. For a group activity, use a designated spotter who watches for lightning. Follow the rules that were decided in advance.
- **When thunderstorms develop**
  1. Estimate distance to lightning using the flash-to-bang method (section 3, next page).
  2. Know how long it will take to reach shelter from where you are.
  3. Determine whether the storm is approaching your position.
  4. Take action in ample time to avoid the lightning.

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- **Lightning nearby**

  1. Go inside a vehicle with a solid metal top. Safe vehicles include a car, bus, van, or the cab of a truck. Don't contact any metal.
  2. Go inside a building normally occupied by the public or used as a residence by people. In general, all-metal buildings are safe if a person stays low in the middle and keeps both feet together; a metal-topped building with stone or other non-conducting walls is not safe. Don't touch anything connected to the power, phone, television cable, or plumbing entering a building from the outside.
  3. Don't stand under or near a tree; stay away from poles, antennas, and towers.

- **Last minute**

  If precautions have been ignored, crouch on the balls of your feet with the head down. Don't touch the ground with your hands.

Other concepts are also explained in response to the two questions above. The following answers avoid the reactive mode:

- Lightning currents coming up from the ground are so strong that shoe type does not matter.
- A lightning flash originating in a cloud 6 km (20,000 ft) overhead is more likely to hit the tallest object.
- Since the average distance that a flash searches to strike ground is on the order of 50 yards (meters), where you are located relative to other tall objects is very important.

This flow of discussion sometimes results in dissatisfaction from the questioner because it was hoped that a quick, easy approach to lightning safety would be given.

When these concepts are explained, less time is spent on the don'ts of lightning safety. For example, when hiking in the Colorado mountains on a July afternoon in a forest far from vehicles or buildings, there may be no better action than to seek a thick grove of small trees surrounded by tall trees, away from individual trees. At that point a listener realizes that safety here is more statistical than absolute.

Despite the need for proactive planning, some literature on lightning safety shows people in outdoor sports who are crouching in an open area. That message is reactive and not the complete plan; the message should also include planning ahead and avoiding the situation.

3. FLASH TO BANG

The distance to lightning from a location can be found using the fact that light travels enormously faster than sound. The distance to lightning using the "flash-to-bang" method of 5 seconds per mile has been taught for a long time. Yet it appears to be known correctly by roughly half of trained science teachers, much less than half of science students, and an equally small portion of the general public. In the metric system, the distance is 3 seconds per kilometer.

The "flash-to-bang" method is described in Vavrek et al. (1993a,b; 1994a,b) as:

- When you see the flash
- Count the seconds to the bang of its thunder. Divide the number of seconds by five for the distance in miles from you to the lightning.

The result of such timing is that a flash five miles away takes 25 seconds for its thunder to reach the observer. In demonstrating this interval during a talk, the audience quickly realizes the length of this time period.

The other aspect of the flash-to-bang method is to determine a safe distance. A Florida study by Krider (1988) found the average distance between successive ground strikes in the same storm was two to three miles. This distance corresponds to 10 to 15 seconds from flash to bang. Other types of storms in other locations and other seasons have not been examined for this distance.

For safety purposes, then, we always recommend a longer flash-to-bang time than 10 to 15 seconds when shelter should have been reached.

In contrast, there is a false alarm problem. Thunder can often be heard up to 10 miles (16 km), corresponding to 50 seconds flash-to-bang; sometimes it is audible as far as 20 miles away (32 km). Should all precautions be taken immediately on the first sound of thunder? Our experience has shown that most people who are frequently involved in outdoor activities will not follow an overly restrictive policy such as this. Instead, thunder is identified as the wakeup call to the threat of lightning. The distance, direction, extent, motion, and growth stage of the storm producing the lightning should be assessed immediately. Actually, the situation should be monitored earlier to be aware of the first flash from a storm. If a thunderstorm is far to the north and moving northeast, the threat is less than when lightning is three miles away and seems to be coming closer. When people know the flash-to-bang method and follow the storm situation, common sense starts to be used. They are more aware of the situation and are taking personal responsibility for their exposure to lightning—this is the main goal.

Some relevant results from a study by Holle et al. (1993) in central Florida were:

- The end of the storm is very important. As many lightning casualties occurred after as before the peak lightning activity. So the flash-to-bang method must be applied until thunder has receded completely.
- Low flash-rate storms had more casualties than high-rate storms.
- The conclusion is that relatively few people are casualties of lightning during heavy rain and high flash rates in the middle of a storm. Instead, low flash rates before and after the strongest portion of the storm are very important. Low flash rates also occur on the edges of thunderstorms as they pass a location.

4. POSTURE RELATIVE TO GROUND

The posture of laying flat on the ground continues to be mentioned in some materials. More recent research shows that ground contact is an important source of casualties from nearby lightning strikes to ground (Andrews et al. 1992).

While it is good to be as low as possible, it appears that lightning more often enters the victim through the ground compared to a direct strike from overhead. The person, then, should crouch on the balls of the feet, with the head down. Don't touch the ground with the hands.

5. EDUCATION VERSUS WARNINGS

Some of the public expects that automatic measurement equipment being monitored by someone else will take care of their responsibility for tracking the lightning threat. In large installations such as the Kennedy Space Center and some outdoor recreation and utility operations, such systems are in place and have been tested for usable thresholds.

For most people in daily situations, however, there is not likely to be a product from the National Weather Service or other agency that will pinpoint the exact place and time of a person's vulnerability to lightning. Instead, each person must take responsibility for their own situation. This is the main reason why education is being emphasized for lightning safety.

In the case of team sports, a ***designated spotter*** on site should watch the sky for the storm situation. Experience shows that many coaches and officials are so involved in the games that they are unwilling or unable to monitor the development of the storm situation at the same time.

6. EDUCATION ACTIVITIES

The authors have undertaken a number of projects for lightning awareness and action. It should be mentioned that an excellent paperback book on many aspects of lightning is Uman (1986). Activities include:

- **Flash to Bang article**
  The same article with slight variations has been published in several science teacher magazines at the state and national levels (Vavrek et al. 1993a,b; 1994a,b). It was intended as an instructional and resource tool for science teachers and their students, coaches, officiators, bus drivers, and school administrators who are responsible for the safety of students and others outdoors.

- **Poster**
  A 16 x 20-inch poster was developed by Howard and Holle (1994) on avoiding trees during thunderstorms. A flash fills the poster as it strikes and illuminates a tree; the same photo is in Uman (1991). The vicinity of trees is the single most common location across the country and around the world where people are victims of lightning. The initial audience is for school children by having the poster placed as a reminder near school doors and entryways. A first printing of 3000 copies was made and sent to science teachers in many organizations across the country, as well as to interested members of the public and media.

- **Underreporting of lightning casualties**
  A more complete measure of the lightning threat ranks lightning nearly as high as most other types of severe weather in the average year. In some states lightning is the greatest threat from thunderstorms during most years. López et al. (1993) and Mogil et al. (1977) used regional datasets to show that lightning casualties are underreported, especially in the case of injuries.
- **Scenarios of lightning casualties**
  In-depth analyses of activities and locations of past lightning victims were made for Colorado (López et al. 1994) and central Florida (Holle et al. 1993). Verbal narratives in *Storm Data* were used to extract more detail than in the past for these states. Discussions with the public, media, teachers, and personnel in the National Weather Service have benefitted from better identification of scenarios that have lead to lightning casualties in their areas.

7. SUMMARY

It is suggested that lightning education needs the following:

- A major reemphasis toward proactive planning.
- More emphasis on proper lightning-avoidance activities must be transmitted to students through the education system, especially in schools, as part of science courses.
- Better knowledge about proper behavior to avoid lightning must be transmitted to the adult public through a broad range of better-prepared literature and other media.

A useful approach is to reach segments of the population that spends a substantial amount of time outdoors through magazines and publications targeted for such activities as fishing, climbing, and bicycling.

In summary, the suggested approach for lightning safety is to follow these steps:

1. Plan ahead
2. Avoid dangerous lightning situations
3 Don't be, or be connected to, the highest objects.

8. ACKNOWLEDGMENTS

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P1.22

HOW'S THE WEATHER UP THERE ?
... DOWN THERE ?
... OVER THERE ?

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INTRODUCTION

In July of 1993, the Third International Conference on School and Popular Meteorological and Oceanographic Education took place in Toronto, Canada. People from all around the world gathered to discuss what is happening and what can happen in the realm of Education. As an educator, I was inspired by the dedication of these people to spread the news that the weather was an excellent medium which could call young people throughout the world to study Mathematics and Science. I was also very much aware of the global concern for education. Being from a very small rural community, I began to feel that my students were missing a whole world outside of their community. Perhaps my colleagues would share my interest in other communities around the world. Once again weather became the central factor. We began asking, "What's the weather like where you live?" By the conclusion of the Conference, many of us who attended went home ready to start new projects. This brings us to the program which I would like to share with you today.

IN THE UNITED STATES

Fall of 1993 began with a series of meteorological disasters. Hurricane Emily was threatening the East Coast. My students wondered what being in a hurricane was like. So we wrote letters to two of our Atmospheric Education Resource Agents (AERA's), asking what the weather was like. In addition to learning what the East Coast was experiencing, my students were able to sympathize with their fears, for many of my students had experienced the Flood of '93. Then, in October, came a letter from Lisa in Southern California. She was experiencing the strong Santa Anna winds which were feeding the fires around her home. She told us that she was afraid to go home after school because her house may not be there when she returned. She addressed her letter to : Anyone Who Cares. My class was quick to respond. Her letter was answered best by Anthony who wrote:

"Dear Lisa,

I know how you feel. This year there was a big flood. There was less than 100 yards that were separating us

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separating us from the river ...I never left my house because I was afraid (that) I would not have a house when I came back...We are praying for you. We will keep you in our thoughts.

Anthony "

As you can see, weather events have brought students together in a much deeper way than I ever thought was possible.

IN CANADA

The Conference was held in Toronto, where I met another enthusiastic colleague, Yvonne Bilan-Wallace, from the Atmospheric Environment Service. She was working with students from the Arctic Circle as well as from Edmonton, Alberta, her own community. With Yvonne's help I was able to contact Karen Eastlake and Linda Manson, teachers from the Gold Bar Elementary School. Students from my classes adopted their students and friendships flourished. My students were amazed that the Canadian children could play in the snow at recess! The Canadian children wondered why we would get a day off from school just because it snowed a couple of inches! We talked about how the different countries measured the temperature. One Canadian student asked, " Why don't you use metrics? Do you know what they are?". Both schools exchanged videos of what a typical day is like at their schools. We found it very interesting that the climate of each community affected how they lived.

IN JAPAN

The International Conference provided me with many contacts throughout the world. I was most fortunate when I met Dr.Tsuneya Takahashi from the Hokkaido University of Education. Through our facsimile machines, we corresponded with an English class at the local junior high school. Unfortunately, the mail is quite slow and we have found that the faxes are much more effective. We exchanged "slang" saying and discussed earthquakes. We discussed our different cultures. My students were amazed that the Japanese students did not celebrate Christmas! We did learn that they celebrate New Years. So, we mailed "care packages" at the end of year (December). Three months later, the Japanese students had their first Christmas Party. The students enjoyed Christmas cards, stories, a miniature tree and tear-jerker gum. My students enjoyed New Year Cards and Omoochi. We are still not too sure of how to eat it, though.

IN NEW ZEALAND

We were very anxious to have a pen pal from the Southern Hemisphere. It was hard for my students to comprehend a place where all of the seasons were the opposite of what they had experienced. Thanks to the International Conference, again, I met Ms. Jenny Foggo of the Correspondence School in Wellington, New Zealand. She put me in contact with Mr. Jock McPherson at the Sacred Heart School. We learned right away that things were different "down under". We received their first letters in May of 1994. WHY? Because the students in New Zealand were only beginning their school year. Unfortunately, we start our summer vacation when they start their school year. Perhaps the seasons are the opposite of each other. We are looking forward to discussing environmental issues. The students are especially concerned with ozone depletion. Who better to ask than our new friends?

IN AUSTRALIA

Our Australian AERA, Russell Legg, has introduced us to a colleque of his from Brisbane, Mr. Graham Jordan. He sent a copy of the weather page from his local newspaper. This inspired our latest project. For six months, each school will save the weather pages from their local papers for a 5 day period each month. (From the 10th to the 15th) Then each school will send a copy of the map to the other 4 schools. Each month we can share weather data and see the differences in climate. Students can then graph and analyze the data, looking for patterns in the various hemispheres. (North, South East and West)

CONCLUSION

The Third International Conference has opened up a whole new world to my students. I can only assume that our pen pals have made just as many exciting discoveries. With the help of my colleagues, my students have learned a treasure chest full of new knowledge about other people who are not so different from themselves. We began by talking about the weather and have become friends. We have learned that through books we gain knowledge, but through friendship we gain understanding.

P1.23

A POLAR EXPRESS - NEW YORK TO TEXAS

Rose Marie Camarda

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Syracuse, New York

It all began with a simple phone call from an AERA from Texas. There was a teacher in McKinney, Texas who wanted to pair up with a teacher from another part of the country and exchange Biome boxes.

It sounded like a great idea, especially since we were studying the Earth's biomes and what better way to help students truly understand the differences than to have the real things there to touch and hold.

We agreed to work on the boxes with our students for the next month or so and then mail them to each other at the same time. However, as most of us know, when you work with children, nothing is predictable and many plans are changed from minute to minute. The boxes we never simultaneously sent.

When the idea was presented to my students, everyone was excited. Our problem was -- how to get all 125 students involved at the same time. We decided that the best way would be to do this project in our Academic Excellence Period at the end of the day.

Each teacher on the team chose a topic, such as, plants and animals, industry, geography, etc. Each class brain stormed what they thought would be appropriate to enclose in a Biome box of our area. The students had several ideas but were forced to be limited by the constraints of box size and ability to be mailed. They soon realized that live specimens were not a good idea.

An even bigger challenge came when the students realized it was February - where would they get flowers, leaves or even soil samples to include. We were under snow and everyone knows nothing grows in Syracuse at this time of year, or do they?

They were not happy about their options. They decided they could video tape and photograph what it looked like here this time of year and draw pictures of what they wanted to share about the rest of the year. So research began and students began to develop collages and other collections of what they wanted to share. One group even developed a board game to go along with some of the information they were sending.

Another class decided they would chart the winter weather we were having and give the students in the land of sunshine some idea of what it was like here in the winter. They began to chart daily temperatures, barometric pressure and humidity. Daily observations of the sky were made and recorded. One group measured the snow each day and began to make a snowfall strip. They would measure the snowfall each day, cut a strip of paper equal to this amount and tape them together. Each piece was dated and the amount of snow listed on it. They now had a visual representation of the months snowfall. Since this was a very snowy winter, they also decided to make a snow strip to depict our snowfall from November to February. The total before the box was mailed was 170+ inches.

The students were still a little frustrated. They wanted to send something real to their new friends in Texas. Thus came the idea of sending a box of snow to them. Everyone was very excited. Now they had a real challenge. Could they really send snow and have it get there before it melted.

The first problem was how to pack it? Some students called a local meat packer and found that things could be shipped if packed in dry ice. The packer explained a way to pack it in a styrofoam cooler with dry ice at the bottom and layers of plastic for insulation. It seemed simple in theory. Finding a styrofoam cooler in Syracuse in February was no easy task. Rounding up the rest of the packaging was a relatively easy task, we had plenty of snow and plastic bags to wrap it in.

Just when they thought they were all set, someone remembered DRY ICE. After some searching a student learned that there was a company in Syracuse that makes dry ice and we could buy some from them.

It was now the end of February and the students felt we better get the snow out before we ended up getting an early thaw and there wouldn't be any "good" snow to send. After a little more discussion, they decided that we would have to send it next day air to be sure it didn't melt.

A student checked with UPS to see if we could send the snow and how much it would cost. The results of the call were overwhelming to them. It seems that Dry Ice is considered hazardous substance and had to be dealt with in a specific way. They were really disappointed. To them it seemed an impossible task since UPS had tried to discourage them from mailing the snow.

After making a few calls that evening, I had everything we needed including the fees to send the package. I did not say anything to the students all day. I tried to let them come up with solutions on their own. During AEP that afternoon, we solved all of the problems, packaged the snow and at 2:05 it was on its way to UPS for quick trip to Texas.

Waiting to find out if it made its journey safely was almost as hard for them as getting the package mailed in the first place. The suspense was unbelievable. Finally the call came through. The package had arrived and it was still snow. The students there were making a video of its arrival and there reactions and it would be sent to us soon. Sending the remainder of our Biome box seemed almost anticlimactic to the students after sending the snow.

This was a great experience for my students. It provided them with a real life situation that had to be problem solved and the satisfaction of knowing THEY had really done it.

P1.24

OKLAHOMA SCHOOLS VIEW THE 10 MAY 1994 ECLIPSE

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1. INTRODUCTION

Over 60 Oklahoma K-12 classrooms participated in a unique learning opportunity during the 10 May 1994 annular eclipse. Teachers and their students observed clouds at predetermined times from 9:30 AM to 1:30 PM and recorded their observations. The observations were returned to the Oklahoma Climatological Survey to be used as validation of cloudiness near many of the 111 automated weather stations of the Oklahoma Mesonet. The Mesonet, which typically records measurements at five-minute intervals, was modified to measure air temperature, wind speed and direction, pressure, and solar radiation at *one-minute intervals*.

The student observations were found to be useful to verify convective activity during the eclipse. Observations and Mesonet-measured solar radiation indicated that while convection initiated in many areas by 9:30 to 10:30 AM, there was a significant decrease in convective activity during and just following the time of maximum annular eclipse.

In return for helping with ground observations, the teachers were sent an information packet that contained the following items: a general description of the Oklahoma Mesonet; a map of Mesonet site locations; graphs of temperature, wind, and solar radiation data for both the closest site to their school and the Mesonet site which best denoted parameter changes during the eclipse; and suggested questions that could be used with the data, including comparisons with their own observations.

The response of the teachers and their students was very positive. Several teachers wrote notes stating that they would enjoy participating in future activities. This article will describe the experiment and some of its results.

2. ANNULAR ECLIPSE OF 10 MAY 1994

The annular eclipse of 10 May 1994 was visible within a large swath through the United States, from southern Arizona to southern Maine. The center of this path was aligned from north of Sayre, OK, on the Texas/Oklahoma border, through Ponca City, in north-central Oklahoma. Locations within about 120 km northwest and southeast of the line, including Oklahoma City and Tulsa, also fell within the path of annularity (Fig. 1).

The peak of annularity began at 11:27 AM CDT in western Oklahoma and at 11:41 AM in the far northeast corner of the state. The duration of the Moon's anti-umbral shadow lasted from a couple minutes at locations on the edge of the shadow to six minutes for those along the center path. For more information regarding this eclipse, see NASA Reference Publication 1301 (Espenak and Anderson, 1993).

3. DATA SOURCES

The Oklahoma Mesonetwork (abbreviated "Mesonet") is a network of 111 automated observing stations that continuously monitor a number of important air and soil parameters (Crawford, *et al.*, 1992). Parameters measured at each Mesonet station include temperature, relative humidity, wind speed and direction, solar radiation, pressure, rainfall, and several soil temperatures.

Every 15 minutes, data observed at 5-minute intervals are relayed from each of the remote stations to a central processing site at the University of Oklahoma. The network is specially designed with two-way communications that allow project staff to conduct uncommon experiments, if necessary. The first operational test of this capability occurred on the day of the eclipse, when the data transfer routines were modified to transmit air temperature, solar radiation, wind speed and direction, and pressure at one-minute intervals.

Verification of general cloud coverage was conducted by over 60 K-12 schools statewide.

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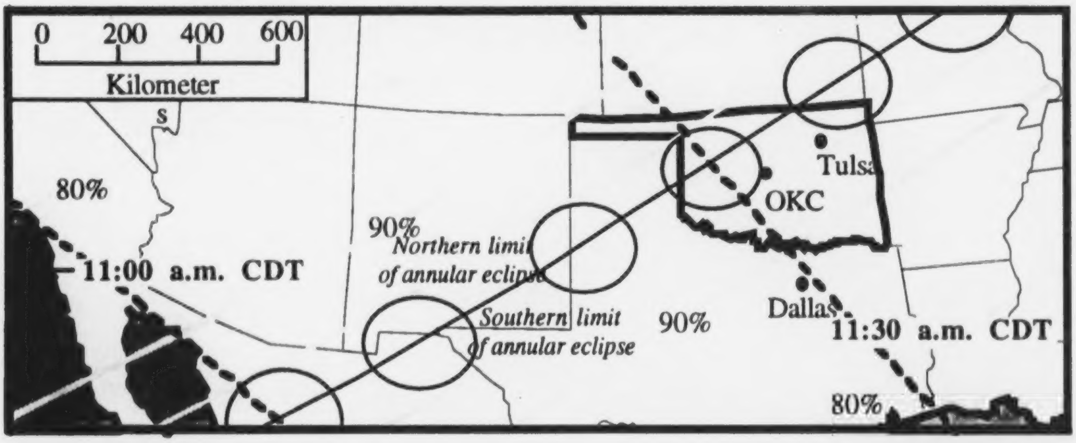

Figure 1. Moon's umbral path during the 10 May 1994 annular eclipse. Derived from Espenak and Anderson (1993).

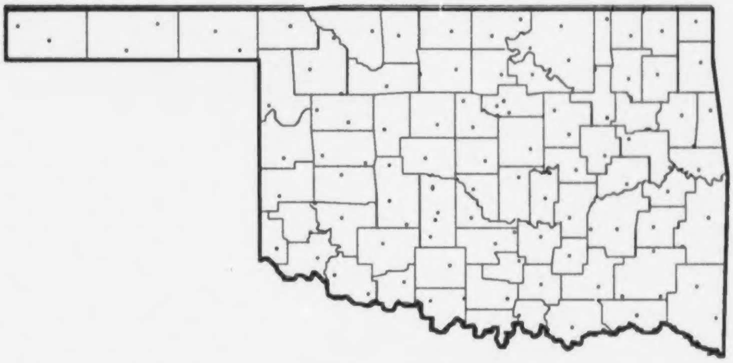

Figure 2. Location of the 111 Oklahoma Mesonet sites.

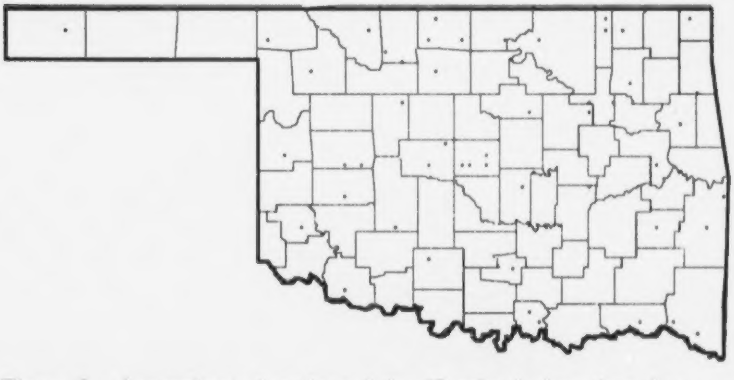

Figure 3. Approximate location of the 62 school observing sites, representing 50 towns.

Observations were taken at 9:30 AM, 10:00 AM, 10:30 AM, 11:00 AM, 11:15 AM, 11:30 AM, 11:45 AM, 12:00 PM, 12:30 PM, 1:00 PM, and 1:30 PM CDT. Figures 2 and 3 show the locations of the Mesonet sites and the school observers, respectively.

4. THE EXPERIMENT

The experiment was conducted as an extension of the Oklahoma Climatological Survey's Project EARTHSTORM. EARTHSTORM is a National Science Foundation-funded educational outreach project that educates teachers to use data (preferably in near-real time) from the Oklahoma Mesonet. Discussions of the EARTHSTORM Project and its software can be found in Crawford, *et al.*, 1993 and McPherson and McPherson, 1994.

There were five main steps to conduct this experiment: (1) mailout of inquiries for interested teachers, (2) receipt of names and addresses from the teachers, (3) mailout of data/lesson package, (4) receipt of school observations, and (5) data analysis.

The mailout of inquiries contained four parts: (a) the registration form for teachers to complete and return, (b) the instructions on how to take the observations, (c) the data form to record each time's observations, and (d) a guide for safely observing the eclipse. The dominant problem that was encountered was how to get this mailout into the hands of interested teachers (i.e., step 1 from above). This proved to be the most unsatisfactory part of the experience. Because no list of state science teachers was available, we sent our information directly to elementary and middle school offices, with a large note marked "Science Teachers!". Out of about 900 invitations sent, we received over 120 replies, a reasonable success (i.e., step 2 from above). However, only 62 of these schools returned their cloud observation forms (i.e., step 4 from above).

The data/lesson package included: (a) a small, color Mesonet brochure describing the Oklahoma Mesonet, (b) a map of the Mesonet locations across Oklahoma, (c) a number of graphs of data, including solar radiation, air temperature (at 1.5 meters above the ground), and wind speed and direction (at 10 meters above the ground), graphed at 5 minute intervals, and (d) a set of questions and answers that could be modified for the particular classroom. Data from two Mesonet sites were enclosed in each packet; one site was the nearest site to the school's location and one site was that which best showed the eclipse effects (i.e., near the center of the path under mostly clear skies).

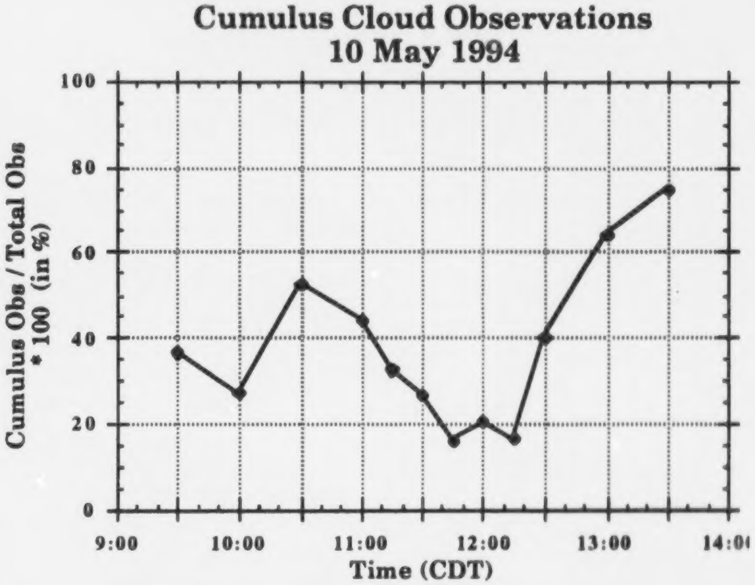

Figure 4. Cumulus cloud observations in Oklahoma during the 10 May 1994 annular eclipse. The line represents the percentage of locations that reported cumulus clouds.

Because elementary through high schools participated in the experiment, the questions were directed at an intermediate level, allowing the teacher to adapt them to his or her grade level. All comments we received about the questions were positive.

The 12 questions relied on both the student observations and the Mesonet graphs. Students were asked to describe their experiences and to relate them to the graphs of measured parameters (e.g., temperature and solar radiation). A number of questions were included to stimulate deductive reasoning, especially for cause-and-effect events. A vocabulary section was added at the end of the activity to provide scientific definitions for the teachers to use.

Time (CDT)	Number of observations
0930	41
1000	59
1030	59
1100	57
1115	55
1130	60
1145	56
1200	54
1215	49
1230	55
1300	53
1330	48

Table 1. Total number of cloud observations reported at the given observation time.

One of the most essential assets of the eclipse lesson was the inclusion of suggested answers. Our experience has shown that teachers are more likely to use previously unfamiliar materials or data if answers are provided.

5. RESULTS

This experiment was conducted primarily to encourage students to observe and analyze environmental conditions, to provide teachers with a unique data source for an event of high interest, and to determine if these school observations may be useful to scientists in the future. Results of these goals, while not dramatic, were encouraging.

On the morning of 10 May 1994, about two-thirds of Oklahoma was covered with anvil cirrus from large thunderstorm complexes in the Texas Panhandle and western Texas. Many towns not covered in cirrus were enveloped in early morning fog that gave way to hazy mid-morning skies. Hence, conditions were not favorable for viewing the eclipse over most of the state. Although we anticipated that these conditions would encourage *more* schools to take cloud observations (as an alternative to their previously scheduled activities), it seemed to keep more classes indoors, except for during the peak of the eclipse.

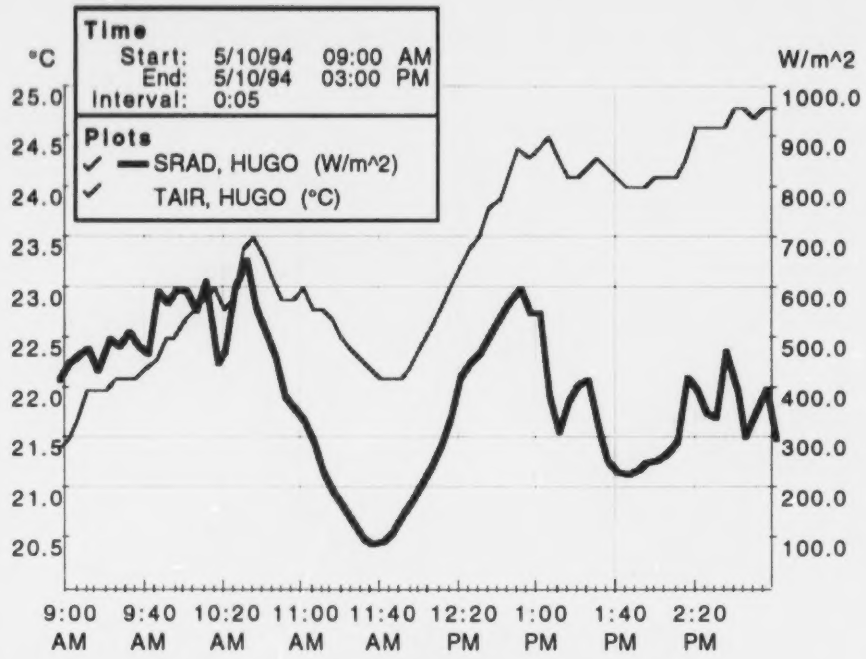

Figure 5. Mesonet observations of solar radiation (SRAD, thick line) in Watts per square meter and air temperature at 1.5 m (TAIR, thin line) in degrees Celsius on 10 May 1994 at Hugo, OK. Note the jagged curves before 11:00 AM and after 12:30 PM. The graph indicates possible convective activity at these times.

School observations confirmed the thickness of both the upper and lower level cloud cover in most areas of the state. However, the most notable cloud observation was the significant decline in cumulus development during the time of peak eclipse. Figure 4 illustrates the percentage of school sites that recorded cumulus development during the observation times. Note the decrease in cumulus observations beginning around 11:00 AM and continuing until about 12:30 PM. Table 1 lists the number of observers for each observation time.

An example of how Mesonet measurements and school observations coincide is shown in Figure 5 and Table 2. Figure 5 depicts the solar radiation and air temperature fields at the Hugo Mesonet site in far southeastern Oklahoma. The decrease in solar radiation during the eclipse is evident between 10:30 AM and 12:30 PM, with the peak occurring at 11:35 AM.

Although cloud cover is not directly measured at any Mesonet site, a number of inferences can be made using solar radiation data. First, solar radiation values lower than the anticipated value at a given time of day and day of the year typically can be attributed to cloud cover. Second, significant changes in solar radiation values which occur irregularly during mid-morning hours may indicate cumulus development. This latter correlation between solar radiation and cloud cover suggests cumulus activity between 9:00 and 10:30 AM and after 12:30 PM at Hugo, OK on 10 May 1994 (see Fig. 5).

Human observations at Hugo (Table 2) confirm the cumulus activity. In particular, although cumulus clouds were present on the morning of 10 May, they dissipated during the hour before and after peak annularity, after which cumulus clouds redeveloped.

6. SUMMARY

The described educational activity was the first of its kind attempted by staff at the Oklahoma Climatological Survey. Although it is not monumental in either scope or substance, the activity offered schools information and support not provided typically by a state university. The experiment also educated K-12 teachers about the basic operation and measurements of the Oklahoma Mesonet, which is uniquely operating in *their* state.

The school observations were valuable to scientists, even with the ambiguous nature of selecting participants by general mailout. However, the use of observations by scientists should not be the overriding factor that determines whether this type of activity is worthwhile. More importantly, were the students able to learn something about their environment that they would not have learned or been able to understand as well without the activity? Unfortunately, proper evaluation of the impact of this experiment was excluded because of lack of time and finances. Nonetheless, we were encouraged by the interest of the schools and hope to arrange further activities for teachers.

7. ACKNOWLEDGEMENTS

Funding for EARTHSTORM is provided by the National Science Foundation through grant TPE-9155306.

I congratulate the staff of the Oklahoma Mesonet Project for their superior performance transmitting and archiving one-minute data at all 111 sites. I appreciate the work by Ray Hardy III, Karen Bivins, and Paul Gray to disseminate and analyze the volumes of information we sent and received. Sue Weygandt and Mike Wolfinbarger assisted with the figures. The NASA Space Grant Consortium is thanked for their help and their financial assistance. Finally, I offer special thanks to the teachers and students who participated in this experiment.

Observation Site: Hugo Middle School, Hugo, OK
Teacher: Hoyt Thompson

Time (CDT)	Observation
0930	**Cumulus** low and to the south and south-southeast approximately 2 miles away. Cirrus directly above and in all directions.
1000	Low **cumulus** to north and east 2-3 miles away. Cirrus directly above to south, west, and north.
1030	Several small **cumulus** directly above, slightly to north, west, south; a large one to east, 1-3 miles away. High cirrus northwest to northeast
1100	Low **cumulus** to north about 2 miles and to southwest about 1 mile. High cirrus above.
1115	High cirrus only covering most of sky.
1130	High cirrus only covering most of sky.
1145	Cirrostratus covering sky.
1200	Cirrostratus covering sky.
1215	Cirrostratus covering sky.
1230	Low **cumulus** stretching across south from east to west about 5 miles away.
1300	**Cumulus** clouds covering sky.
1330	**Cumulus** clouds covering sky.

Table 2. School observations of cloud activity on 10 May 1994 at Hugo Middle School in Hugo, OK. Note how the observations of cumulus development coincide with the solar radiation curve in Figure 5.

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P1.25

A GUIDE TO TORNADO PREPAREDNESS PLANNING IN SCHOOLS

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1. INTRODUCTION

If a tornado were to threaten your school campus this year, would you be prepared? The importance of developing a school preparedness plan and routinely practicing tornado drills has been well demonstrated. Hundreds of lives have been saved in the United States during recent years as tornado safety plans were activated by school officials prior to the onslaught of a devastating tornado.

One of the most effective means to reduce the potential for tornado deaths and injuries in schools is to promote school tornado safety drills. Planning before the storm is vital to insure prompt and proper action during the storm. Administrators of schools should be familiar as to which portions of their buildings offer the best shelter if a tornado strikes.

Information in this article will guide you through steps in developing a preparedness plan for your school and in conducting tornado drills to cope with nature's most violent storm. It will familiarize you with the proper actions necessary to safeguard students during an actual tornado threat. Hopefully, the time spent reviewing these guidelines will provide the necessary preparation to implement a disaster plan in the future. Seconds can truly save lives!

2. TORNADO PREPAREDNESS PLANNING

Several studies have indicated conclusively that tornado preparedness planning before the storm and prompt action upon recognizing storm signs reduce the potential for loss of life and injuries. Preparedness plans and routine drills insure that both students and faculty react effectively when severe weather occurs. It has been documented that on numerous occasions many lives have been saved when a school official sounded the alarm that moved students from temporary classrooms into the hall of the main building moments before a tornado hit the school.

Not only is the tornado nature's most violent storm, it is perhaps the most unpredictable. The current state-of-the-art technology only provides potential warning times on the order of seconds and minutes. Important advances in the science of meteorology and new technological capabilities for observing and analyzing the atmosphere, will likely provide unprecedented weather service improvements in the next decade. However, warning lead time will still usually be on the order of minutes. In fact, severe thunderstorms can and often do produce tornadoes with little or no advance warning.

The average number of tornadoes per year for the entire United States in the period 1961-1993 was just over 800 with an annual average of 82 fatalities and nearly 1700 injuries. The spring semester months of April through June hold the highest occurrence of tornadoes on a seasonal basis, although tornadoes have been documented in every month of the year.

Many tornadoes strike during the middle to late afternoon. Unfortunately, there is a coincidence between school dismissal times and the occurrence of potentially dangerous thunderstorms. All schools are encouraged to keep informed of developing thunderstorms in their area, since advanced planning before the storm is vital to schools dismissing for the day.

3. DEVELOPING A TORNADO PLAN

There are several elements to developing a good tornado plan. School officials and faculty members should be alert to the warning signs of severe weather and tornadoes. All school systems should have access to National Weather Service statements and have a method for internal dissemination of this severe weather information. An understanding of severe weather terminology, especially knowing the difference between a Watch and a Warning, is of vital importance.

Each individual school should be inspected to select and mark the safest areas for protection from

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a tornado or severe thunderstorm. Periodic tornado drills should be held at all facilities to insure that both faculty and students will respond in a predetermined manner when an actual tornado or severe thunderstorm approaches the school.

4. SOURCES OF WEATHER INFORMATION

Perhaps the quickest way a school can receive a severe weather watch or warning is by listening to the National Oceanic and Atmospheric Administration (NOAA) Weather Radio. Reception is generally confined to within a forty mile radius of each transmitter site. This service provides continuous broadcast of weather information on VHF-FM frequencies between 162. 400 and 162. 550 MHz.

Although normal programming can be useful to a school system in its daily operations, it is during severe weather that the NOAA Weather Radio proves to be invaluable. All watches and warnings which affect the area within radio range are broadcast immediately on the NOAA Weather Radio. An advantage of the system is that it is not necessary for the receiver to be continuously monitored to receive a warning. A special tone is transmitted just prior to the watch or warning which activates special "Tone-Activated" receivers and turns them on. If possible, each school within radio range should have such a receiver. They may be purchased at most electronic outlet stores.

School systems outside of the range of NOAA Weather Radio must rely upon other sources of information such as local radio, television, Civil Defense, or Emergency Management agencies to relay National Weather Service bulletins. Arrangements should be made with one or more of those information sources to pass reports of severe weather to the school system. If a tornado develops suddenly, this may be the only warning received.

5. INTERNAL DISSEMINATION

It is imperative that each school system develop a plan for rapid internal dissemination of severe weather information especially Tornado Watches and Warnings. Each school should have a complete list of emergency phone numbers such as fire, police, Civil Defense, and Emergency Management. Since every school in the system needs to be notified, one possible method of distribution is through the use of a pyramid notification system. This can be accomplished either by radio or telephone.

A special alarm system should be designated at the school to indicate a tornado has been sighted and is approaching. A backup alarm system should be planned for use if electrical power fails. Perhaps a battery-operated bullhorn, an inexpensive hand-cranked siren, or even an old-fashioned hand-swung bell would be beneficial.

The resources and capabilities of each school system vary greatly, and each plan must be developed with this fact in mind. Children are our greatest resource, and everything possible must be done to assure their safety.

6. SEVERE WEATHER WARNING SIGNS

There are a number of severe weather warning signs that each school principal, administrator, and faculty member needs to become familiar with. In fact, any one of these persons might be the first one to observe a potentially dangerous storm or make the critical decision to act. In many cases, there may be no official warning of impending danger. Each school official should not hesitate to call a drill when the weather is threatening.

Tornadoes, by definition, are violent, rotating columns of air in contact with the ground. The main distinction between a tornado and a funnel cloud is that a funnel cloud remains aloft and does not produce damage. Special attention should be given to very dark, turbulent clouds that exhibit swirling motions. When a tornado touches the ground, there usually is a swirl of dust and debris even when the visible cloud portion is missing or fails to reach ground level. You can generally assume when viewing a funnel cloud at a distance and it extends halfway from the cloud base to the surface, that it is probably a tornado.

Hail of any size generally indicates the potential for more severe types of weather. Often, large damaging hail will fall nearby or to the immediate north and northeast of where tornadoes occur within a severe thunderstorm. If giant hail falls at your location, you are in or very near the most dangerous portion of the storm. In addition, strong winds, dangerous lightning, and frequent thunder could be early warning signs of a severe thunderstorm. These are nature's warning signs that the thunderstorm is in its most violent stage.

A thunderstorm does not have to produce a tornado to pose a danger to schools and students. Damaging straight-line winds, referred to as downbursts, can produce strong localized winds that can be as great as those of strong tornadoes. Lightning may pose a threat well before strong winds or rain affect the area. Generally, if you're close enough to hear thunder, then you are close enough to be struck by lightning. A continuous rumble or roaring sound has been known to accompany tornadic thunderstorms although engineering studies indicate that debris flying with the wind could produce these sounds.

While watching for tornadoes, special attention should be given to the skies in the west and southwest since most tornadoes form adjacent to and usually on the southwest side of the heavy precipitation.

7. SEVERE WEATHER TERMINOLOGY

An understanding of severe weather terminology is vital. All school personnel should understand the distinction between severe weather Watches and Warnings. When the National Severe Storms Forecast Center in Kansas City, Missouri, issues a Severe Thunderstorm or Tornado Watch, it means that severe thunderstorms or tornadoes are likely to develop. This is a time to keep a watchful eye on the sky for threatening weather, and stay tuned to local radio, television or NOAA Weather Radio for the latest weather information.

All warnings are issued by local National Weather Service offices. A Severe Thunderstorm Warning means that severe thunderstorms capable of producing damaging winds and/or hail equal to or greater than 3/4 inch in diameter are in the immediate area. A Tornado Warning means a tornado has been sighted or indicated by weather radar. Persons in the path of the storm should seek shelter immediately, preferably on the lowest floor of a substantial building.

Remember, in some cases there may not be time for a tornado warning to be issued before a twister strikes. Tornadoes do form suddenly! Teachers and students should know the difference between a Watch and Warning and must be able to take appropriate action whether or not a warning is issued during a threatening weather situation.

8. ACTIONS DURING A WATCH

There are a number of occasions in which a severe weather Watch will be issued when skies are clear and appear to pose no immediate threat. However, severe weather can develop rapidly and the Watch may be the only precursor of a threat before the storm develops.

During a Watch, school administrators must monitor local radio, television, or NOAA Weather Radio for the latest available weather information. Since a tornado or funnel cloud could be obscured by precipitation or darkness, faculty members should keep an eye on the sky for dark, swirling clouds, dangerous lightning, large hail, driving rain, and any sudden increase in wind speed.

School district administrators should insure that the Watch information is received by each school through a predetermined dissemination system. All school bus drivers should be alerted to the threat and should know beforehand what actions to take. In the event of a disaster, administrators should be prepared to utilize school resources to aid in the relief process.

Individual school principals need to notify all faculty members of the Watch and caution them to be alert for a possible drill. When threatening weather approaches, post teachers, administrative and maintenance personnel about the school grounds to watch for potential severe storms. Finally, make sure that telephone lines remain open and available to receive any additional information.

9. ACTIONS DURING A WARNING

Once a Tornado Warning has been issued, it is imperative that the communication of the warning occurs as fast as possible and a tornado drill is initiated immediately thereafter. Each school district must relay the warning to individual schools without delay, monitor all available communications for additional reports and information, and suspend operations of school buses if possible.

Individual school administrators need to initiate a tornado drill at the school campus immediately. A special alarm signal should be sounded to indicate a tornado drill and a backup alarm should be available for use if electrical failure occurs. It is highly recommended that a battery operated bullhorn, a hand-cranked siren, or even a hand swung bell be available.

Students in classrooms should be moved to designated shelters. Those students who are located in temporary buildings or schoolrooms of weak construction should move to shelter areas in a permanent structure. If school buses are still at the school, students should be unloaded quickly or prevented from boarding and be moved to designated shelters. Specific teachers should be assigned to round up children on playgrounds, athletic fields, or other outdoor facilities. Otherwise, they might be overlooked. Since weather conditions can change rapidly, school officials should continue to monitor radio or television to determine when the threat has ended.

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10. SAFEST PLACES IN SCHOOLS

Quite obviously there are numerous variations in building construction. However, most buildings offer a significant amount of protection for normal occupancy of the facility. It is essential that all schools be inspected and that the safest areas for protection from a tornado be selected and marked.

There is no single disaster plan that can meet the needs of every school system. Normally, an on-site inspection of a school by a trained wind engineer, architect, or Civil Defense official can determine those portions of a building which will offer the greatest protection if a tornado strikes.

There are a number of places in most schools that offer safe refuge during a threatening weather event. In schools without basements, the interior hallway on the lowest or ground floor offers the best protection. Since it has been documented that most tornadoes approach from the west or southwest, you should choose a hallway that will not be parallel to the tornado's path. If possible move to a hallway that is at right angles to the approaching tornado's path. It is also preferable to utilize an interior corridor that opens to the east and north where the wind force will usually be least. These hallways offer the best protection from strong winds and dangerous missiles.

There are a number of objects that can serve as potential projectiles and need to be avoided. Students must be able to move swiftly to interior corridors that do not have glass windows or glass doors.

If a tornado is approaching, should students or faculty members open the windows of classrooms? Latest engineering studies indicate opening windows is not desirable. In fact, opening windows might allow wind blown debris to enter the building resulting in structural damage to walls, windows, or the roof of the school. It is desirable, though, to close the classroom doors leading to a designated hallway shelter area to reduce the potential for harm.

In addition to hallways and interior corridors, rooms with short roof spans are desirable. A good rule of thumb is to choose a small room with no load-bearing walls. In fact, spaces where the roof system is supported by columns, rather than walls, will usually be safer.

If your school has a basement or underground space, use these as designated shelters. In general, when selecting locations for designated shelter areas in your school building, choose areas that can be reached from all portions of the building in less than two minutes.

11. POTENTIAL AREAS TO AVOID

Every school building contains vulnerable areas that cannot be relied upon to withstand tornadic winds effectively. Large roof span areas such as auditoriums, gymnasiums, cafeterias, or libraries should be avoided. These rooms almost always have high ceilings and walls and excessive glass windows and doors. Often these large spaces receive maximum damage and if large groups of people are present, major loss of life and numerous injuries could result.

Avoid upper floors, especially the top floor. Load-bearing walls are the sole support for floors and the roof above. If winds cause the supporting walls to fail, part or all of the roof or floors will collapse. Rooms that have exterior windward walls many times receive the full strength of the winds. Windows on the windward side will likely be shattered and blown into the rooms.

Students in school rooms of weak construction, such as portable or temporary classrooms, should be evacuated. Escort these students to sturdier buildings or to predetermined ditches, culverts, or ravines, and instruct them to lie face down, hands over heads.

12. PROTECTIVE POSTURE DURING A DRILL

Periodic tornado drills should be held at all facilities to ensure that staff and students will all respond properly when an actual tornado or severe thunderstorm approaches a school. Each school administrator should call a drill anytime weather conditions appear threatening. Severe weather usually lasts for only a short time and little time will be lost from classroom activities.

When students are assembled in school basements or interior hallways during a tornado drill or Warning, they should be instructed to respond to a specific command to assume protective postures. If danger is imminent, have students lie face down toward an interior wall within the inner portion of the school. Have students draw their knees up under them, and cover the back of their heads with their hands. Protecting your head is important since most fatalities in tornadoes result from head injuries due to flying debris.

One example of a command that school officials might use is: "Everybody down! Crouch on elbows and knees! Hands over the back of your head!" It is essential that this command be instantly understood and obeyed. Illustrations showing the protective posture should be posted on bulletin boards for emphasis.

13. SCHOOL BUS CONCERNS

Policies governing the use or non-use of school buses during tornado Watches and Warnings need to be established before the threat. Whenever a Tornado Watch is issued, alert school bus drivers of the threat and insure they know what actions to take. Buses should normally continue operations during a Watch. If a warning is issued or a tornado is observed, school administrators should delay operations of school buses if possible. If students have already boarded a school bus, but are still at the school, then they should be moved inside.

If a school bus is trapped in the open country, students should be removed from the bus and escorted to any available reinforced structure or seek shelter in a nearby ditch, ravine, or low lying area. Students should be instructed to lie face down with hands over head. Extreme care should be exercised that students seek refuge a safe distance from the bus. School buses are easily rolled by tornadic winds!

In the event a tornado strikes suddenly without time for evacuation, bus drivers should be instructed to evade the tornadic path by driving at right angles to the storm. School bus drivers should be regularly drilled in tornado procedures.

14. DETERMINING THE BEST AVAILABLE TORNADO SHELTER

Every school is vulnerable to the potential ravages of tornadoes. School officials planning to build new school buildings or additions should keep tornadoes in mind when setting construction standards. For optimum planning purposes, both school board members and engineers should participate in the design of new buildings and develop an emergency plan for protection during threatening weather situations.

Numerous inspections of schools damaged or destroyed by tornadoes indicate that the worst effect of a tornado on a school building is an intense blast of wind from the combination of the tornado's rotational velocity with its forward speed. Approximately 90 percent of all major U. S. tornadoes come from a direction somewhere between southwest and west-southwest. With this in mind, school administrators can determine, in advance, those portions of their buildings that are likely to be safest or most dangerous if a large tornado directly impacts their building.

Figure 1 is an illustration that shows a floor plan for a one-story elementary school with an enrollment of 508 students plus 32 staff, with 3,240 square feet of "best-available shelter locations" shaded in black. Researchers indicate that if a large tornado hit this school, some persons occupying some of the locations would be injured, but most likely there would be few if any lives lost.

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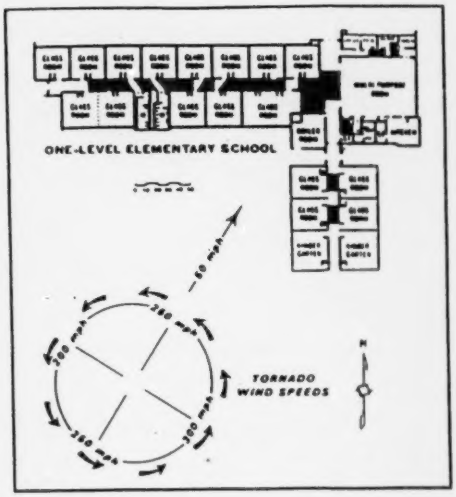

Figure 1. Best available tornado shelter. From The Safest Places In Schools, James J. Abernethy, 1975.

P1.26

ATMOSPHERIC CLASSROOMS: THE FUTURE IS NOW

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1. INTRODUCTION

Only a few years ago computers, interactive television, bulletin boards, and ham radios were looked upon as future dreams and possibilities. Those dreams are now reality. The future is here.

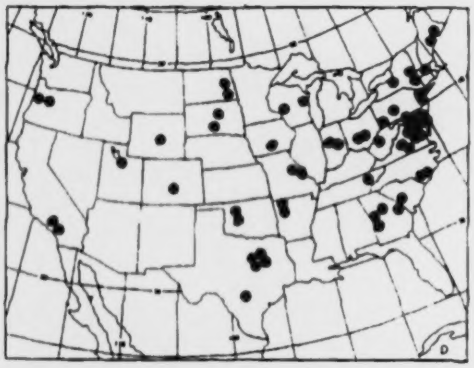
America's precollege classrooms are undergoing an exciting technological transformation. Most teachers and students no longer "read the text and answer the questions at the end of the chapter." Computers, television, and media have become the focus of instruction. Atmospheric Education Resource Agents (AERA's), in adapting to this change, have embarked on several programs to initiate change and inform personnel of the latest innovations involving meteorological data acquisition.

Project Atmosphere's Resource Agents serve as links between the American Meteorological Society, and the precollege educational community at all grade levels across the United States. "AERA Actions" have included workshops and share-a-thons with numerous professional organizations. Some of the organizations involved in these interactive programs are: Fire and Forest Meteorologists, The Weather Channel, National and State Science Teachers, Federal Emergency Preparedness Directors, Broadcast Meteorologists, Civic Clubs, and The American Red Cross. Resource personnel play an important role in the exciting changes occurring in meteorology and atmospheric subject matter. Partnerships between professional personnel and educators are the key to the successful transition from textbook methodology to active, motivational studies in all areas of science.

Highlighting a successful year in meteorological technology were the "Kids as Global Scientist Project," the "DataStreme Feasibility Study" and the "Weather Kids Project." Students, teachers and professional atmospheric experts worked closely with AERA's in implementing programs that brought a new meaning to education and knowledge acquisition.

2. DATASTREME

Obtaining real weather data while still current is beyond the technical and financial resources of most schools. Project Atmosphere's DataStreme Project is an inexpensive system that supplies the data teachers and students want. The first year of the feasibility study was notably successful. Figure 1 shows the location of Agents participating during the 1993-94 school year.



The DataStreme Project is a cooperative effort with cable television's The Weather Channel, the National Science Foundation and the American Meteorological Society participating. The WSI Corporation is assisting by delivering weather data to The Weather Channel for the study.

Serving as a Science Consultant and AERA in Columbus, GA, I was able to work with teachers and students at Dimon Elementary School and at the nearby Fort Benning Department of Defense Wilson School. The media specialist and lead teacher at Dimon Elementary set up the computer, television, and receiver in the library enabling students and teachers in other grades to access data needed for specific projects. Fifth and sixth graders utilized DataStreme to study climate by comparing weather data from around the country. Higher grade students mentored primary students and provided assistance as they used current data in math and language arts.

"Wilson fifth-graders become weather-wise" was the headline on the front page of *The Bayonet*, a newspaper published on the military base at nearby Fort Benning, Georgia. Complete with colored photographs, the article featured the students, school and teacher involved in DataStreme. Highlights of Jerrie MacIntire's report during a school board review of the project provided the following observations concerning the success of the program:

"Fifth-grade students at Wilson School have become efficient amateur meteorologists and are producing regular weather forecasts while honing other academic skills through a pilot study program. Students obtain daily atmospheric data from a computer link. By factoring such components as temperature, wind speed and direction, humidity, precipitation, and cloud cover, the students forecast the weather for one or for several days.

Atmospheric studies are turned into cross-curricular lessons. Students learn geography when predicting the weather for grandparents, who may live anywhere in the world.

Various weather charts present challenging but interesting math and science lessons, while observation of weather patterns in other geographic regions contribute to social studies lessons."

An added bonus: the program sharpens oral expression and communication skills as children learn to present their forecasts in a professional manner. Students not only make predictions but are becoming proficient in making presentations in the style of broadcasts meteorologists. Plans for the second year include a weekly news show with weather forecast and the establishment of a telecommunications link with other schools that have the program. An electronic pen pal connection can enhance opportunities for learning at both ends. It can, for instance, provide additional lessons in social studies and geography while sharpening language arts skills through on-line communications.

As a result of the DataStreme/Project Atmosphere program students enthusiastically participate in daily lessons. The weather has become a passion with Wilson student Sarah McClelland. Sarah eagerly awaits the evening news so that she can compare her own weather prediction to that of the local forecasters.

3. KIDS AS GLOBAL SCIENTISTS

Bringing the outside world into the classroom was a major goal of the University of Colorado professor, Dr. Nancy Songer. Working through AERA's and various other educational organizations, Dr. Songer organized groups of Middle School students and teachers in exchanging atmospheric data and information using computers, modems, and bulletin board communication. The program also involved extensive interaction with appointed atmospheric specialists who volunteered to work with students and teachers. Dr. Paul Ruscher at Florida State University in Tallahassee, Florida, served as the "resident expert and advisor" for a large number of schools in the southeast.

Eighth grade students at Richards Middle School, along with their teacher, Mrs. Margie Curtis, and the Principal, Mr. Bill Arrington, communicated with students at 10 international sites and 40 sites in the United States.

The project involved over 1200 students and was conducted through Internet linkages. Each school identified an area of local expertise and interest to share along with current and historical meteorological data. Examples of some group titles were "Mountain Meteorologists, Environmental Patrols, Climatology Experts, and Weather Phenomena Detectives." The correspondence often blended humorous comments along with exchanges of scientific data and expressions of creative insight.

4.1 *Weather Kids*

Local Broadcast Meteorologists Kurt Schmidtz--ABC-TV, John Elliott--CBS-TV, and Dan Brennan- -WGSY/Sunny 100 Radio have included students and teachers in their daily routine of informing the public about local atmospheric conditions in Columbus, Georgia and surrounding areas. Mr. Schmidtz initiated the Weather School in the elementary schools, and Mr. Brennan works with elementary and middle level students in providing on-air weather reports during his three-hour morning broadcast. Each morning students call him on the phone from their respective schools. Dan assists them in composing the information for the report, tapes the information, and rebroadcasts the weather report every 20 minutes. Several students requested an opportunity to do a live forecast, and Josh, one of the elementary second-graders, became a local celebrity during his visits to the Sunny 100 studios.

John Elliott, the CBS-TV broadcast meteorologist, spent many hours visiting students in classrooms talking about weather. He also invited groups of teachers to the studio to learn what he does in preparation for an evening report.

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Teachers and students looked forward to interacting with John and to seeing themselves on the evening news.

4.2 *Summary*

Technology has a new role in classrooms across America. Students and teachers acquire current atmospheric data, interpret, analyze, and synthesize the information for use in many creative and unique ways. Resource personnel facilitate the acquisition of data and interact frequently with K-12 pre-college personnel. They help to bridge the gap between the community, the classroom, and the world. Interactive global communications through technological advances have become a part of the daily activities in the lives of young people. Project Atmosphere/AMS partnerships provided the essential stimulus for this successful, pioneering venture.

P1.27

PREPARING FOR THE FUTURE OF ATMOSPHERIC SCIENCES BY LEARNING ABOUT THE PAST

Natalija Janc*

1. INTRODUCTION

For better understanding of a specific natural science it is necessary to have an basic knowledge about its historical development, to have an insight into the degree of the achievements of that science in specific historical periods, or even encompass its continuity over a few centuries.

Most school curricula contain a subject called *History*, but in most cases priority is absolutely given to the political history, whereas the history of sciences is in some cases only relatively and in other even absolutely ignored. As a good example can serve Columbus' passage across the Atlantic. Most people know the date America was discovered, names of the ships that took part in the venture, as well as names of many personalities involved, but the fact that the discovery was made possible by Columbus' knowledge of the prevailing wind directions and ocean streams, and that exactly those details enabled the success, is not widely known. Undoubtedly, the Vikings had a similar "marine meteorology" knowledge centuries before Columbus.

2. PURPOSE

Meteorology is a relatively young science and it is almost not present at all in the high-school curricula. Many high-school and even college students think that meteorology originated in the nineteenth century, and that some fields as weather forecasting and anti-hail protection are as recent as the middle of our century. Because of that it would be important to give the students an introductory lecture aiming at giving an short historical overview of the meteorological science. It would be advisable to start from the sixteenth century—the period when started a continuous and uninterrupted development of atmospheric sciences until present. An excellent opportunity would be a visit to a science museum exhibition where the development of meteorological instruments and the science as a whole is systematically presented.

3. FIRST STEPS

It should be underlined that the development of physics and mechanics sixteenth and the seventeenth century led to a radical transformation of meteorology. The introduction of individual methods in the description and research of natural phenomena, as well as the invention of thermometer, barometer, and other meteorological instruments, opened the gateway to the scientific research of the atmosphere instead of the mere astrological predictions of weather that were widely accepted during the Middle Ages. Aristotle's *Meteorologica* from the fourth century B.C., which was a standard textbook on the medieval universities, renounced its place to such treatises as Descartes' *Meteorology* from 1637 that greatly encouraged the establishing of meteorology as a branch of physics. This fact readily illustrates the fact that in meteorology for almost twenty centuries there were no major or influential discoveries.

As with many other sciences, the advancement of meteorology was to a great extent determined by the invention of appropriate instruments for measuring and registering the atmospheric phenomena. The most important among them are undoubtedly thermometer and barometer.

Invention of the first thermometer is associated with the famous Italian scientist Galileo Galilei, who used it in his lectures at the beginning of the seventeenth century. At that time, the scientist experimented with various kinds of thermometric fluids as air, alcohol, and, of course, mercury. A big disadvantage of these thermometers were their different scales, so that the temperatures measured could not be compared. With respect to this, an important step forward was done by Fahrenheit at the beginning of the eighteenth century who introduced his type of thermometer and his scale, still in prevalent use in English-speaking countries. Later, about the mid-century, Celsius and Reaumur gave their also very successful constructions of thermometers.

Barometer is an instrument for measuring the atmospheric pressure. Its first construction was given in the first half of the seventeenth century by Galileo's disciple Torricelli. It consisted of an glass tube about six feet long sealed on the one end and then immersed into an open vessel with mercury. Torricelli supposed that the column of mercury in the tube balanced the pressure of the atmosphere on the free surface of mercury in the vessel. Later modifications of his original idea were aimed at constructing a more compact and portable device, and also more precise—being corrected for some effects that Torricelli did not take into account.

The first constructions of hygroscope, instrument for measuring the humidity of the air, were done at the beginning of the fifteenth century in Europe. As a basis for most constructions, the property of some bodies to change their shape with the increasing humidity was used. Some other constructions were based on the changes of weight of the bodies absorbing the moisture.

The English scientist Hooke in the seventeenth century intensively worked on the construction of meteorological instruments. Among them was also the wind

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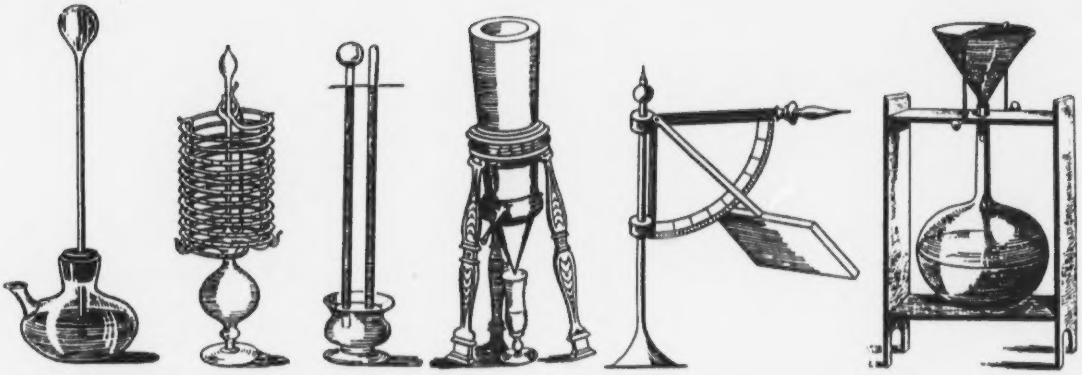

Figure 1. a) Galilei's air-thermoscope; b) Florentine thermometer with three hundred divisions; c) Torricelli's barometer; d) Hygroscope filled with ice. e) Hooke's wind-gauge; f) Hooke's rain-gauge.

gauge, used for measuring the direction and intensity of the wind. Its principles are very similar to those of its modern counterparts. A small plate was freely swinging around a bar that was moving over a graduated scale. With stronger wind the plate would be farther blown away, showing the intensity of the wind.

Records of precipitation also have a long history from India about 400 B.C. and Korea from the 15th century. But the major developments again occurred in seventeenth century in Europe. The fundamentals of rain gauge construction were correctly posed from the very beginning, so that even the early attempts show a big similarity to the modern instruments.

4. METEOROLOGICAL OBSERVATIONS AND THEORETICAL FOUNDATIONS

A series of continuous meteorological observations came from the seventeenth century. At that time the importance of simultaneous and independent observations was recognized. Among elements measured was also the atmospheric pressure with intention to estimate the possibility of a weather forecast based on variations of the pressure. A specially designed form for registration of meteorological data was published and prepared as a model for meteorological reports.

The construction of meteorological instruments enabled the beginning of regular meteorological measurements. Simultaneous discoveries in physics of the laws in the dynamics of fluids, as well as other laws about gases and liquids, was the cornerstone for further development of meteorology. Boyle's formulation of the law relating the pressure, volume and temperature of a gas, gave rise series of attempts to find the height of the atmosphere and to establish the relation between altitude and atmospheric pressure.

At that time, meteorology was not being developed as an independent science. Some theoretical articles were written by philosophers, physicists, mathematicians and astronomers. Among them was Descartes, French philosopher and mathematician, who gave a theoretical explanation of the rainbow. His theory about the rainbow is probably the first example of utilizing a physical law to explain a phenomenon done in a correct way and final. The English astronomer Halley gave a barometric formula for the altitude; the French mathematician and philosopher D'Alembert gave a theory of wind origins; the American printer, publisher, inventor, scientist, and diplomat Benjamin Franklin contributed to science with his experiments with electricity showing that cumulonimbus clouds possess electricity and that the lightning is in fact an electric spark.

5. CONCLUSION

Generally speaking, the history of natural sciences and technology is an important part of basic education contents contributing to a better understanding of the development of human civilization. In this article we intended to give only some remarks about facts that would be beneficial to include into curriculum. The quantity and depth of information depends of the age of students, time available, as well as other circumstances.

Because the weather and climate are such an important part od our everyday life, some elementary knowledge about meteorological instruments and their use should be incorporated in everybody's education.

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P1.28

A New Look to the Sky

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EarthWatch Communications and other 3-D technical products have stormed into many homes, in the Dallas Ft. Worth area, taking many viewers on a hydrological field trip equal only to the high tech special effects on the current movie screens. Traveling through the atmosphere at speeds equal or surpassing the speed of the space shuttle viewers at interact firsthand with current weather systems from their neighborhood to their neighboring states. Usually the viewers of the local weather broadcasts are adults: however, many children are tuned into the broadcast to experience a ride unequal to the last as the rotate in and around severe thunderstorms and developing storm systems.

No weather text in school today offers the 3-D phenomenon which opens the door to an understanding of cloud development, temperature location variation and weather system movement. People remember and understand when given the opportunity to experience a concept firsthand. Past and present educational background traditionally presents weather education as a "flat and stationary model." Something is lost in the divorce of nature's fluid characteristics.

Children are excited to see the likeness of the clouds they experience on the ground and rotate to the top and all sides of them. Their world is multi dimensional. The 3-D products are going beyond their original expectations in just presenting the weather. Children watch the clock for their opportunity to interact with the products. They are looking up outside to see if they can "make a match" with their observation and the product's observation. Most importantly these children are bringing in the adults in their life to the screen and they are talking to each other. This common bond of our atmosphere is truly going beyond just a showy product.

The educational community has been given an awareness, by students of a wide age range, to a new look to the sky. When students come to school, they have a personal data base of stored information to bring higher order thinking skills to science. They are helping to bring an awareness to the adult population that did not have the benefit of the technological advancements that are being experienced today. Teachers are addressing questions from a 3-D perspective. Students want to make a model rather than just draw a picture.

It is exciting to experience an unpredicted avenue that new technology has traveled without having made an intentional turn. Educators invite and appreciate free resources and the opportunity to bridge school, home, and community together. Besides, we are all on the one planet we share together.

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accelerated in presenting the water cycle in its sometimes overwhelming ability to be out of balance of its traditional presentation. Observing the world around us, in this constant cycle, will give a meaningful understanding to teachers and students alike.

P1.29

From the Ground to the Sky

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The theme of this year's conference, "Opening the Door to the Future: Education in the Classroom and Beyond," is very fitting to our efforts to enhance atmospheric education. In fact to open the door, that door must be established. Reflecting on our own educational experiences as children, little to no time was ever spent on our atmosphere other than the study of the seasons. Our own personal interest and curiosity of the atmosphere has been our challenge for further information and understanding of the atmosphere. Children have a natural curiosity about the world around them, especially the world above their head. Prior knowledge is a springboard to continued investigations which our atmosphere provides on a constant basis.

There is a defined need for the enhancement of atmospheric education as the American Meteorological Society has recognized. The study of science of any kind does not start in the seventh grade but that first day of kindergarten at the average age of five. As classroom teachers and scientists we have come to a mutual agreement in recognizing the limited changes in the content of the science cirriculum and its delivery. In the average classroom in the United States, one will find desks, chalkboard, bulletin boards and a traditional cirriculum which in most cases reflect the classroom of the 1800's. We have set out together to make a change. It is even more fitting to promote this change with the advancement of technology available for classroom use and the modernization of the National Weather Service.

Combining our own special interests of the atmosphere, we are organizing material which include the topics of floods, thunderstorms, and tornadoes. Both of us being native to Tornado Alley, we can relate to the youngest of children in a natural curiosity of these atmospheric events. Although there are large differences in learning capabilities between elementary grade levels, the material will be presented in the following divisions: that suitable for kindergarten and first graders, and that suitable for second and third grades. The text will appeal to the listening level of kindergartners and the reading levels first through third grades. Also included will be easy to organize and manipulate hands on activities to enhance the concept of these significant weather events. Hazardous weather was chosen because it is one of the most important subdivisions in weather studies. Also, it is important for students to learn safety rules associated with tornadoes, lightning, and flash flooding, especially as children do not always have an adult around for help. Safety rules will undoubtedly get taken home so that adults in the family can also be informed. Even with the most reluctant of classroom teachers who hesitates to address science past a token representation, this material will help him or her develop an understanding of these events through a language arts approach. This effort will allow the early introduction of scientifically based weather phenomena in an age appropriate fashion. Teacher will be able to use this material which on a very primary level will clear up common misconceptions about weather events and possible stumbling blocks in the subject so the teaching can be accurate and current technology addressed. Lessons in the classroom can be aided in the use of the materials. The science process skills will be seen overlapped in the several academic areas.

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The content of the materials will be reviewed through a panel of atmospheric scientists in the field as well as on the university level. This partnership of the scientific community and the classroom will provide students the knowledge of the research and findings of the current state of the art technology, it availability, and its on going observation and investigation of significant atmospheric events.

P1.30

USING SCIENTIFIC THEORY AS METAPHOR TO ENHANCE EQUITY IN URBAN PRIMARY SCHOOLS

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1. INTRODUCTION

The evolution of human consciousness hence the organization and assimilation of information regarding our surrounding environment hitherto has been dominated by an anthropocentric i.e. "self centered" field of reference. This phenomenon in part is the biproduct of stereoscopic vision which is directed radially outward from a central vantage point resulting in a three dimensional perception of space. This linear perception of space in turn has permeated the entire field of human thought thus affecting every facet of consciousness from social structure and dynamics to a constellation of scientific paradigms, which in turn influences morals, values, and the way in which the human species perceives its place within the cosmos in general. For instance, the system of Newtonian mechanics developed during the 17th century (which still prevails as a significant edifice in modern physics) is a classic example of the linear geography which had dominated the human mind especially during that particular period in history. However the development of the quantum and relativity theories, which represent a cornerstone of scientific thought during the 20th century marks a critical threshold of transition in consciousness whereby the previous constellation of scientific paradigms, which were primarily three dimensional and "clockwork" oriented underwent substantial modification and rearrangement thus emerging as a more four dimensional, hence "field oriented" system of thought. Thus the perception of space, time and matter had evolved from a spacial and fragmented view toward a perception in which these respective entities became integrated to form a continuum, or field-like organization in which the element of time assumes a more interconnected role within the dynamics space and matter (which defines the "fourth dimension" of this respective system). For instance, Einstein's classic work "The Electrodynamics Of Moving Bodies" (which was the title of the original thesis written by Einstein that first introduced the special theory of relativity) represents but an integration of John Clerk Maxwell's paradigm for electromagnetism and the aforementioned paradigms for Newtonian mechanics. Additionally, Einstein's theory of general relativity is but a paradigm rearrangement and modification of Newton's universal law of gravitation in which space and time became integrated within the universal gravitational field to form a geometric four-dimensional space-time manifold. The quantum theory transformed the age old Democritin paradigm for the atom from a mechanical model which emulated the solar system to a paradigm that decomposes the atom into a complex and dynamic field in which waves and particles interact thus yielding packets of energy, or "quanta". In fact, the "field paradigm" can be extended to the area of psychology in which Carl Jung developed a paradigm for a "collective consciousness", or field of human behavior which in turn can be broken down into "archetypes". (Although Mr. Jung proclaimed himself anti-mathematical, this concept nevertheless has a distinct mathematical signature and can easily be compared to the chaos theory pioneered by Edward Lorenz in which spontaneous organization, or "attractors" are analogous to the concept of archetypes which arise within the field of human consciousness as described by Jung.) Biology in fact is not exempt from interpretations of the field paradigm. Rupert Sheldrake's theory of "Morphogenetic Fields and Formative Causation" which describes the organizational forcing of matter through a system of templates, or "morphic fields", as well as J. Lovelock's Gaia Hypothesis which defined the terrestrial biosphere as a single self-regulating homeostatic living system, both represent innovative manifestations of the field paradigm. Perhaps the most profound example of the field paradigm is the Grand Unification Theory in physics which attempts to integrate the four component forces in the universe into one unified force, or "superforce" during the first explosive picoseconds at the beginning of time. Thus there has been a distinct drift within the "collective human consciousness" (as described by Jung) toward a unified perception of nature which has commenced especially during the 20th century. In fact the recent shift in the global political state and the depolarization of the "superpower" structure may be the very first permeation of this unified, or field perception within the realm of socio-political organization. Although the subsequent political state is at present volatile, this could represent but a temporary transitional phase toward a more unified political and social state (analogous to the catastrophe theory in mathematics in which an entire system becomes radically transformed from one state to another, with the latter state assuming a markedly different organization as compared to the original state). In addition, modern technology and the "feed-back loop" hence proliferation of satellite imagery of the Earth as a whole planet (without the superimposition of geopolitial boundaries etc.) has served to reinforce, albeit on a subconscious level, the idea of socio-political unification, or in more contemporary terms the "New World Order."

2. THE "RAINBOW CONNECTION": BASIC CONCEPT

The Rainbow Connection is an educational concept designed to reconcile this recent evolution in human consciousness in which a field oriented, or unified view of nature forms the central thesis around which the curriculum is not only structured but in fact is the product of unification in itself. For instance, the aforementioned examples of unification in science have obvious conceptual meaning which in turn can be interconnected between their respective disciplines. In addition, the learning modules themselves become unified through a multi-integrated curriculum design i.e. cross-linking between left hemispheric (logical) and right hemispheric (intuitive) regions of the brain whereby curriculum areas that have been traditionally fragmented become integrated such as math and art, science and drama etc. Thus science evolves from a textbook and routine two dimensional "lesson plan" and becomes full, sensory and stimulating learning experience which integrates the mind, body and spirit into one active and dynamic medium.

3. BASIC LEARNING MODULES: SAMPLES

3.1 *The World Horizon Principle*

A metaphor borrowed from the theory of special relativity, the "world horizon" form the boundaries at which a student's world concept terminates, especially within urban environments where the student's physical world view is literally constrained by many tall man-made structures and buildings etc. This sense of constraint can in turn become superimposed hence enmeshed within the student's general psyche thus limiting the potential psychological growth and the way in which they relate to the environment. However, through expanding the student's world horizon to include not only the Earth as a planet but the universe as a single dynamic interactive object, not only does the student's basic concept of space, time and matter increase expotentially i.e. of "what's out there in the world" etc., but the student's sense of unity with the Earth and the universe becomes enhanced. Also, this sense of unity will tend to diminish social, racial and cultural barriers which can sometimes arise in areas of high population density and diversity such as in urban environments.

3.2 *The Duality Principle*

The yin and yang symbol derived from the Eastern ideology of Taoism can be a graphic metaphor in representing an important organizational template in nature. In the now classic book "The Tao Of Physics", Fritjorf Capra relates the dualities of space and time, waves and particles etc. to the principle of the yin and yang. The Rainbow Connection is also based on this principle of duality in that the left-right hemispheric learning (of the brain) becomes, as a function of the yin and yang, a dynamic, interactive circle where one component enhances the other. Also, this principle can be a powerful metaphorical tool which in addition to teaching concepts in science, can also be implemented on the social level to represent unified dualities between various races and cultures etc.

3.3 *Virtual Math*

A metaphor borrowed from the popular new computer technology "Virtual Reality." In the Rainbow Connection "Virtual Math" is an attempt to restore the linguistic element to math. In fact language itself is in essence a symbolic representation of ideas which are manifested in the arrangement of characters specific to the cultural and ethnic orientation of the respective language. Thus when characters within the given language become assembled to form a word, the word then becomes an "enfolded reality" which upon materialization of the word then "unfolds" within both the mind of the user of the word and its recipient(s). (This concept is based on the theory of "Implicate Order" popularized by the renowned physicist David Bohm.) This unfolded reality can either represent the total experience of the user as related to the word, and/or the collective experience of both the user and its recipient(s). For instance the word "Mountain" represents the user/recipients total experience regarding mountains.

In "Virtual Math" this concept translates to the idea that equations can also represent enfolded realities which can range from simple arithmetic to the more complex equations of the calculus: Consider the following examples:

$$a + b = c \qquad g = \frac{GMm}{rd^2} \qquad Rs = \frac{2GM}{C^2}$$

1) 2) 3)

Equation 1 could represent the classic arithmetical problem typically presented to early primary school children e.g. "If John had five apples and Jane had four apples, how many apples would they both have?" Thus the enfolded reality that surrounds the student's concept of apples, the characters in the problem i.e. John and Jane, unfolds in the student's mind which can then assume a variety of forms that can also include the environment which surrounds the problem e.g. space, time, ambient conditions: Were the apples large or small? Were John and Jane in a supermarket or in an apple orchard? Was the weather sunny or rainy? etc. Equation 2, Newton's law of universal gravitation can obviously compose a vast enfolded reality in that gravity is a common everyday experience. Thus "M" which represents the mass of the Earth can be multiplied by "m", which in turn can enfold just about any object or event imaginable from a rocket to the baseball hit by Roger Maris that marked his 61st home run. The product of M x m is then multiplied by the universal gravitational constant and then divided by the square of the radial distance between the object and the center of the Earth. Equation 3 also involves gravity and mass but enfolded in a very peculiar way. This equation, (after a few months of mathematical rigor) was developed by physicist Karl Schwartzchild to describe the gravitational collapse of a given mass (usually a decaying star) to a "black hole" (where G is again the universal gravitational constant, M represents the mass of the object undergoing the collapse, divided by "C", the speed of light squared). In other words, the equation describes the limit the radius of a given mass must compress beyond before undergoing a runaway mutual collapse toward its center of mass commensurate with an expotential increase in its gravitational field. The black hole concept can be immensely stimulating to young students because of the many bizarre phenomena, or enfolded realities that can take place especially beneath the "event horizon" i.e. the gravitational boundary beneath which light cannot escape, space and time become distorted, and the laws of nature decompose. Therefore the students imagination, temporarily freed from the constraints imposed by the logical, can run rampant through a veritable wonderland of possibilities from time travel, reverse cause and effect e.g. a baseball that ascends from the bleachers and descends onto Roger Maris' bat before he runs around the bases backward! (In fact reverse entropy, or cause and effect inside black holes is an idea seriously propounded by the celebrated physicist Stephen Hawking.)

Thus, although the basic concept of Virtual Math may not directly address the issue of the actual mechanics of solving a mathematical equation i.e. the computational component, it transforms math from flat two-dimensional array of characters to three and even four dimensional (including the dimension of time) world of the imagination thereby forging a cross-linking between the left hemisphere (logical) and the right hemisphere (imagination). This concept can be effective in dissipating the spectrum of dysfunctions which have traditionally plagued math learning from "math block" to the general apathy students feel toward math because they will "never have use for it in the real world" etc. Also it somewhat ameliorates the feeling of constraint and frustration many students feel as a result of having to conform to the rules and rigor of math concepts as well as giving the student a direct psychological interface with the phenomena described by equations in which they can have some creative input in solving math problems.

4. SAMPLE OF ACTIVITIES

4.1 *Improv Playhouse*

One of the more popular activities at the Rainbow Connection, this learning medium provides a dynamic and creative environment in which topics in science quite literally become a "moving experience!" Thus concepts ranging from the spin of quantum particles (the quark with its whimsical hierarchy of component symmetries e.g. "top, bottom, up, down, charmed and strange" are ready-made for the student's active imagination) to the motions of weather systems across a weather map, to the orbits of the planets are explored through drama and creative movement.

4.2 *Mind Games*

Math and science concepts are both introduced and/or reinforced through this active learning medium. Some of the games developed at the Rainbow Connection are "Hyper-ball-a" (which integrates the spelling bee with baseball), "Einstein Hangman" (similar to the traditional game of "Hangman" only the focus is on the use of science and math words, and additional features are added to the "hang-man" which give him the signature look of that most famous scientist of the modern era!), and "Supersquares", a fast paced and challenging game based on quick responses to questions derived from learned math and science concepts, and the score is added expotentially.

4.3 *Wizards' Workshop*

A learning medium in which children explore science and math concepts through arts and crafts. Some of the projects have included designs using calculus symbols (e.g. the integral, the partial-d, as well the array of Greek letters typically used in calculus such as sigma and tau etc.), created extraterrestrial environments, robots and space craft.

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5. SUMMARY

The primary purpose of the Rainbow Connection is to transform the learning experience in science and math into veritable culture which interconnects the student with the outer universe of clouds, whales, the snowflake and the stars, to the inner universe of inquiry, imagination and creativity through metaphor and a full spectrum of multisensory experiences. Thus math and sciences becomes metamorphosed from a flat two dimensional field of information to a colorful, enriching life-affirming environment where rather than becoming "cognitively stored data", math and science become deeply enmeshed within the psyches thereby influencing the formulation of values, morals, hence word view. The spirit of the Rainbow Connection is best embodied by one of Albert Einstein's most famous quotes: "To imagine is everything."

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P1.34

UNIVERSITY OF WYOMING INITIATIVE FOR RESEARCH AVIATION

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1 INTRODUCTION

The University of Wyoming (UW) has instrumented and operated several aircraft for atmospheric research continuously since the 1960's. One advantage of such an undertaking at a university is the educational advantage this presents to the students. Many advanced degrees have been earned by students working with these state-of-the-art facilities over the years.

Beginning in 1987, UW and NSF began a cooperative agreement to operate the UW research aircraft, a Beechcraft Super King Air 200. Again, the strong educational advantage that having facilities such as these at universities was a large part of the justification for this funding. It occurred to us, however, that relatively few undergraduate students (or graduate students) nationwide in fact gained experience with research aircraft. In response to this, we proposed to NSF an 'Educational Initiative' to make the aircraft available to colleges and universities for projects with primarily educational objectives. In this way, faculty and students who were not necessarily specialists could become exposed to a facility which normally would be too expensive and essentially unavailable for purely educational projects.

Atlas et al. (1989) discussed the education problem related to radar meteorology in particular and with observational science in general in attracting students to continue as scientists and practitioners in these observational fields. It is indeed these issues that we address with this project to make our airplane available to students who might otherwise never have this opportunity.

In this paper, we discuss the UW educational initiative with the King Air, and describe our experiences in fielding this effort.

2. PROPOSAL

Our ideas was for the aircraft to go to the participating institutions rather than the students gathering at a central location such as UW. We therefore had to target a limited area geographically so that a minimum number of flight hours were used for ferry purposes. We arbitrarily chose the northeast US, and wrote letters to individuals at the UCAR universities in that area inquiring about interest and soliciting ideas for student projects. We received responses from six institutions (seven departments) which, along with our own department at UW, became the basis for our proposal to NSF to fund the EI flights. Table 1 contains a list of the institutions and principal contacts for the project.

A total of 10 hours were budgeted for each location (15 hours for Pennsylvania State University since there were two departments involved there which had different objectives). Each site was allocated one week to accomplish the flights. This week included the movement and setup of the airplane and equipment to the site.

3. PROJECT SUPPORT

3.1 *Student Proposals*

The students at each site were to organize around local faculty advisors to develop research projects. Students could propose to work individually or in groups, but this was arranged by the faculty advisors. Staff at UW was contacted to provide technical input into the project plans.

3.2 *Short Courses*

In advance of the arrival of the aircraft, a UW faculty member visited each site and presented a 'short course' on the principals of measurement from an aircraft, the instruments, flight characteristics and flight planning. The exact content of the short courses was different at each site and this depended upon the nature of the projects as they developed, student interests, and faculty expertise.

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Table 1: Participants in UW Educational Initiative in 1993

Institution	Location	Principal Contacts
Lyndon State College	Lyndonville, VT	Bruce Berryman
McGill University	Montreal, Quebec	John Gyakum Rod Rogers
Millersville State University	Millersville, PA	Richard Clark
Pennsylvania State University Atmospheric Science	State College, PA	Dennis Lamb Dennis Thomson
Pennsylvania State University Aeronautical Engineering	State College, PA	Skip Smith
State University of New York at Albany	Albany, NY	David Fitzjarrald
University of Maryland	College Park, MD	Bruce Doddridge Russell Dickerson
University of Wyoming	Laramie, WY	John Marwitz Alfred Rodi

3.3 *Field Phase*

The aircraft arrived at each site accompanied by a crew of three (pilot, technician, and data engineer). A vehicle containing necessary equipment, spares, and a workstation for data processing was also provided.

Students and faculty advisors would handle the tasks of setting priorities for flights on a daily basis based largely upon the weather. Students who were inclined flew on the aircraft as principal investigators and observers.

Data was processed in flight for quick-look purposes and after the flight on the workstation for archiving and analysis.

4. DISCUSSION

We think that the aircraft going to the participating institutions was very important to the apparent success of this project. Had it been the other way around (students coming to UW), we feel that the level of participation and follow through would not have been as high.

On the other hand, our schedule (seven locations in seven weeks) was overly ambitious. Flying ten research hours and then ferrying to the next site and setting up within a week was too much for our crew. If we have the opportunity to do another project like this, we feel that 1.5-2 weeks per site would be a more realistic goal.

One distraction which was perhaps unavoidable was scheduling the visits while classes at the participating schools was in session. This had two effects: i) there was a high level of participation by students and faculty, and ii) the conflict with classes made for a hectic schedule. In sum, this is probably better than having the visits in the summer, for example, when students and faculty would be less available.

One outcome that was not anticipated was that there were at some sites open-houses scheduled, so of which involved K-12 students. Also, the visit of the King Air was integrated in some cases into courses being taught at the time.

In the end, we were surprised at the number of students we worked with on this project. The level of participation and excitement was very high. While original science was not necessary in these projects, we think that it was inevitable that some projects would produce original and publishable results, and feel that this was the case.

ACKNOWLEDGEMENTS:

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P1.35

AN AVIATION WEATHER MINOR AT EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

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1. INTRODUCTION

Embry-Riddle Aeronautical University (ERAU) is an independent, non-sectarian, not-for-profit, coeducational university with a history dating back to the early days of aviation. The University serves culturally diverse students motivated toward careers in aviation and aerospace. Its most popular undergraduate degree is the Bachelor of Science in Aeronautical Science. This 4-year course of study provides the student with a liberal arts background along with flight instruction from Private through Commercial Instrument Instructor Pilot.

2. CHANGING ENVIRONMENTS

Traditionally, ERAU has offered two courses in Meteorology at the undergraduate level: AS 201, Meteorology I, and AS 352, Meteorology II. Meteorology I is an introductory meteorology course similar to that taught at other universities. Meteorology II expands upon that foundation and applies it to aviation. Some members of the faculty felt that more aviation-related weather topics would enhance the flying safety of young pilots and, indeed, quench the thirst that most aviation enthusiasts have about the "wind beneath their wings."

Additionally, it was felt by some that an experience vacuum was developing as Federal agencies became increasing dependent upon automated systems of weather observing and briefing delivery. Because pilots no longer have the luxury of being briefed by an experienced weather forecaster, Aeronautical Science faculty sensed a need for more classroom instruction in what we call "Aviation Weather." Topics concerning severe local storms, climatology, and weather observing and forecasting products, and weather on other planets were explored for inclusion into a Minor in Aviation Weather.

3. NEW COURSE DEVELOPMENT

Three new courses were developed and first taught in the Fall of 1992. AS 363, The Thunderstorm (and Its Environment), explores everything a pilot needs to know about severe local storms. AS 261, Aviation Climatology of the World, introduces the student not only to general climatic classifications, but also to the differing flying weather conditions caused by geography and by season. AS 364, Weather Information Available to Aircrews, expands the student's focus from national to international perspective; from Fahrenheit and millibars to Celsius and hectopascals.

"The Thunderstorm Course" (as the students call it) focuses on the proper atmospheric setting for development of both the airmass thunderstorm and the squall line thunderstorm. Students learn to assess the atmosphere's stability and potential for convective development. A course-ending project has teams of students developing rules of thumb for short range forecasting of thunderstorms.

"Aviation Climatology" takes the student around the world to investigate the causes and ramifications of climate over the seven continents. A project helps to focus each student on the weather patterns at a specific location.

"Weather Information For Aircrews" explores the various weather observation and forecast products from around the globe. It introduces the student to the

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changes taking place within those Federal agencies responsible for providing weather data to the aviation industry. Products from commercial venders are also addressed. Additionally, a week of study is devoted to the use of airborne weather radar.

4. A DYNAMIC CURRICULUM

The 15-hour Minor in Aviation Weather has proved to be popular with students. Feedback from graduates indicate that they believe their employment opportunities were enhanced by the amount of aviation weather knowledge gained. Besides the five courses mentioned above, a graduate course in Advance Meteorology (MAS 517) is also available for credit toward the Minor. Future plans call for the development of a course on "The Weather of Other Planets': a course that will satisfy requirements not only for the Minor in Aviation Weather, but also for the Minor in Space Studies.

Embry-Riddle Aeronautical University, a long time leader in Aviation Education is posed to become the international leader in Aerospace Education, too.

P1.36 STUDENT PERCEPTIONS OF CLIMATIC CHANGE

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1. INTRODUCTION

During the past twenty years, the subject of climatic change has grown from an obscure corner of the academic world to a subject of considerable scientific, educational and media attention (Ausubel, 1991). This interest has resulted in many articles in both news magazines (*TIME, U.S. News and World Report*) and the popular scientific press (*Environment, Smithsonian, Scientific American*). With all this media attention, both teachers and students have had considerable exposure to climatic change as both a scientific and public policy issue. What do students really know and understand about climatic change? How are these perceptions related to views of their own local weather? The goal of this research was to survey college students in introductory geography/meteorology classes on these topics. Eighteen colleges and universities cooperated in the study. The survey solicited information on five topics: demographics, media exposure, experience with unusual weather, opinions about local climate, and familiarity with processes related to climatic change. The results indicated a high level of student awareness concerning climatic changes and a generally held belief that such changes will affect both global climate and local weather.

2. BACKGROUND

The possible consequences of climatic change have sparked a debate concerning public policy which has increased media attention even more. For example, the April 22, 1991 issue of *TIME* magazine carried a report on the debate within the White House on climatic change. One group says it is time to act while the opposite camp says there is still plenty of time, so "wait and see" is the best policy. Meanwhile weather events continue to command media attention. *Time* magazine, March 14, 1994, published an article called "Burned by Warming". This piece focused on the financial losses incurred by insurance companies due to hurricanes and other large storm systems and speculated that climatic change could bankrupt the insurance industry.

Many human activities can potentially contribute to a changed global climate (Firor, 1990; Jaeger, 1988). The principal concerns are global warming, ozone depletion and environmental degradation. Carbon dioxide enrichment of the atmosphere is the culprit in scenarios of global warming. Carbon dioxide is a relatively small constituent of the atmosphere (about 0.03%), yet it is one of the most important heat absorbing gasses in the atmosphere. If the atmosphere traps heat more effectively, the global temperature could rise even though the amount of insolation remains the same. This is the greenhouse effect. Predictions are that during the period from 1850 to 2050, carbon dioxide levels will have doubled. The source of this additional CO_2 is the burning of fossil fuels (predominately coal and oil). As more of these fuels are burnt, CO_2

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concentrations increase in the atmosphere, and the lower atmosphere traps more heat radiating upward from the earth's surface. Thus the lower atmosphere warms and climate presumably seeks a new equilibrium with unknown changes in seasonal weather patterns and extreme events (Easterling, Parry and Crosson, 1989; Mearns, Katz and Schneider, 1984). There is much debate as to the form of this new equilibrium or what policy measures, if any, should be enacted to deal with the CO_2-climate change connection (Ausubel, 1991; Katz, Ausubel and Berberian, 1985; White, 1990; White, 1988.)

The second source of concern is the potential depletion of stratospheric ozone. Ozone absorbs nearly all of the sun's ultraviolet (UV) energy cascading into the upper atmosphere thus providing a kind of protective shield for life on this planet (Stolarski, 1988). The culprit is a class of chemicals called chlorofluorocarbons (CFC's). Upon release from industrial processes and refrigerants, these can, little by little, rise to the stratosphere and through a series of chemical reactions break down the protective ozone molecules. Since this is a catalytic reaction, the CFC's are not destroyed in the process. Thus their concentrations increase in the stratosphere and destroy even more ozone.

Measurements in both the Antarctic and the Arctic have shown serious depletion of stratospheric ozone (Lemmonick, 1992). As more ultraviolet energy arrives at the earth's surface, it impacts life forms and ecosystems in a number of harmful ways. It causes eye cataracts or even blindness, and also contributes to skin cancer. Potentially excess UV can disrupt aquatic ecosystems (Smith, 1992).

The third source of concern deals with global environmental degradation. The clearing of tropical rain forests, erosion of top soil and related processes of desertification modify the earth's surface and thus affect prevailing climate (Firor, 1990; Henson, 1991; Price, 1988; Hare and Sewell, 1986). Much of the focus has been on the rapid destruction of tropical rain forests around the world. Burning of the rain forests adds a significant amount of carbon dioxide to the atmosphere. Since the forest is destroyed, it no longer absorbs the carbon dioxide that it once did in the process of photosynthesis. The destruction of tropical rain forests thus represents a two-pronged attack against the climate system. The Amazon rain forest in particular has become a symbol of all the global human and natural forces that ultimately affect the climate system (Serril, 1989).

With all this scientific and media attention, both teachers and students have had considerable exposure to climatic change as both a environmental and public policy issue. What do they really know and understand about climatic change? How are these perceptions related to local weather?

3. SURVEY DESIGN

This survey was undertaken to investigate the students' degree of knowledge about climate change and the perceived relation to weather in their locale. The specific goals of the survey dictated the organization of the survey instrument. Like any survey the first section solicited demographic information. The second section focused on educational background and media exposure. The third part assessed their prior experience with extreme weather. The survey instrument contained a list of weather events; e.g., thunderstorm, tornado, drought. The students simply indicated events which they had experienced. The fourth part asked them to describe their local climate in terms of hot, cold, wet, dry, seasonal, etc. The final section focused on their knowledge concerning the mechanisms of climatic change. They were asked how familiar they were with a number of key words in the climatic change vocabulary; e.g., greenhouse effect, ozone depletion, GCM. If they noted strong familiarity with a term, it indicated some understanding of process. They were also asked to agree or disagree with statements about processes that might affect climate; e.g., atmospheric pollution, clearing of forests.

An important goal was to determine if the students believed that climate has changed or will change and to investigate the perceived relation between global climate change and local weather. Questions were included on summer and winter temperatures and precipitation compared to the past. They were also asked to agree or disagree with propositions that global climate would change and that the climate of their own state would change.

The data set of 500 respondents was analyzed with descriptive statistics. ANOVA and MANOVA statistical analysis were also used to identify significant relationships between variables. Maps were compiled showing the reported experience with severe weather.

3.1 Survey Limitations

The survey had the usual limitations of such research: (1) Even though eighteen colleges participated, parts of the U.S. were not adequately represented. (2) Most participants were students in introductory level geography or meteorology classes. As such, they might have prior interest or knowledge that other students do not have. (3) Any survey has a definite focus and leads the respondent to some degree. It is clear from the content what orientation or goal is behind the survey. (4) People do not always respond honestly to the questions. Perhaps many affirmative responses should not be as strongly affirmative as they were. Sometimes people are too agreeable. (5) Since the questionnaire was relatively short, only three pages, some of the information was solicited in a very cursory fashion.

4. RESULTS

4.1 Demographic

The typical respondent was 20-25 years of age with one to two years of education after high school. They had had seven to twelve hours of science in college. Slightly more males than females responded. The average length of residence in their respective state was ten years. They tended to be from urban/suburban environments rather than small town or rural environments.

Their reported exposure to the media was questionable for such a population. They reported spending 3-5 hours a week reading newspapers and popular magazines and 11-20 hours a week watching television or listening to the radio. The number of television hours reported was lower than anticipated.

4.2 Experience with Severe Weather

Figure 1 summarizes their experience with extreme weather events. For instance, almost all had experienced a severe thunderstorm, but only two percent claimed to have experienced a tidal wave. A tidal wave is not strictly a weather event but it was included for control. The relatively high percentage who claimed to have experienced a hurricane (43%) or a tornado (42%) was something of a surprise.

The maps of hurricane, blizzard and tornado experience showed strong geographic patterns (Figures 2, 3, and 4). On these maps each dot represents a respondent who reported experience with the particular type of weather event. Given the locations of the responding college as well as the locations for the particular phenomenon in question, the results were not unexpected. For example, respondents who had experienced hurricanes were from sites near the

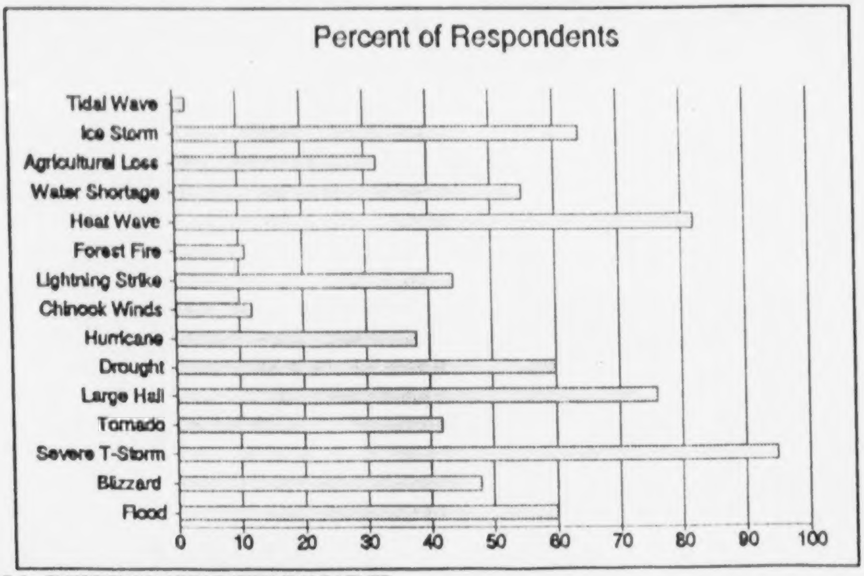

FIGURE 1. EXPERIENCE WITH EXTREME WEATHER

TORNADO

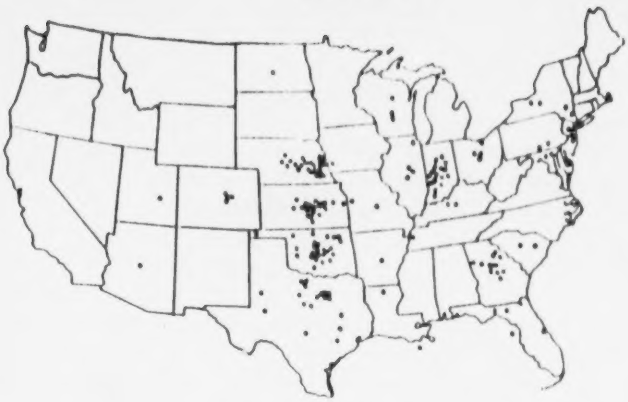

FIGURE 2. INDIVIDUALS WHO HAD EXPERIENCED A TORNADO

BLIZZARD

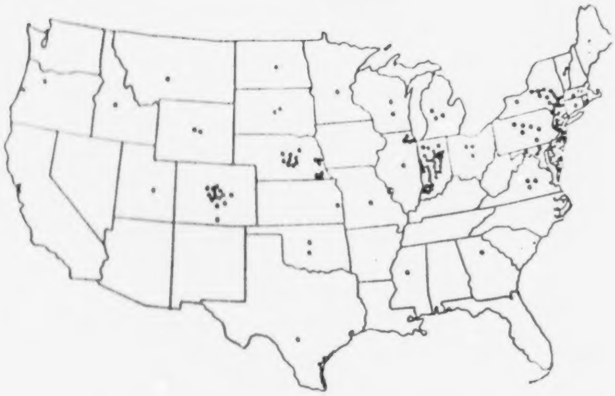

FIGURE 3. INDIVIDUALS WHO HAD EXPERIENCED A BLIZZARD

HURRICANE

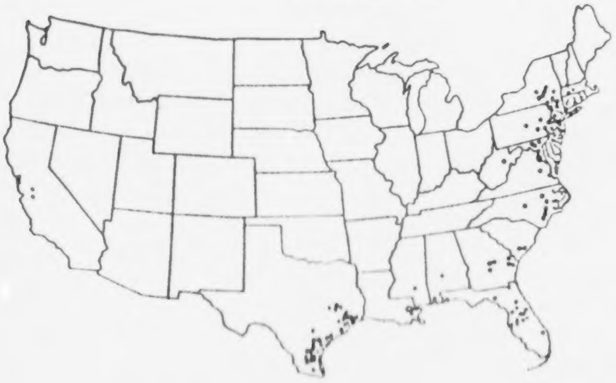

FIGURE 4. INDIVIDUALS WHO HAD EXPERIENCED A HURRICANE

coast. In contrast, experience with blizzards was a more interior phenomenon as was tornado experience. The maps indicated a "Tornado Alley" from Texas to Nebraska and on to Indiana. The locations of reported extreme heat and extreme cold were more difficult to explain (maps not included). One might expect extreme heat in Texas more than extreme cold, but certainly both can occur there. Part of the explanation undoubtedly has to do with the respondent's previous experience and expectations.

4.3 Knowledge of Climatic Change

One of the more revealing parts of the study dealt with the respondents' familiarity with key terms in the climatic change vocabulary. Table 1 summarizes the results; a 5 represents a term with which the respondent was very familiar whereas a 1 indicates no knowledge.

TABLE 1

Green House Effect	3.8
Ozone Depletion	3.6
UV	3.2
CFC's	1.8
TRF's	1.3
GCM's	1.2
RFP's	1.2

The results showed good overall familiarity with the topics that have received the most media attention - greenhouse effect, UV and ozone depletion. CFC's was not a well known term to them. TRF was inserted as a kind of control acronym. However several students used the abbreviation in the context of tropical rain forest. GCM (General Circulation Model) and RFP (Request for Proposals), terms that are well known to professionals, were not meaningful to the students.

Where and how do the students get their information on climatic change? Television is not an important source of information on climate change. Newspapers and magazines seem to have more influence, particularly for the idea that forest removal can change climate. However, the most important source of information was the number of science classes (Table 4). Women seem to be less familiar with some of the terms. This can be explained because women reported a lower number of science hours and less time spent reading newspapers.

4.4 Local Climate and Climatic Change

Table 2 below shows the students' descriprions of the climate of their respective state.

TABLE 2

Hot	56%
Cold	33%
Wet	39%
Dry	40%
Seasonal	50%
Unpredictable	38%

They also responded to statements dealing with environmental processes that might affect climate or contribute to climatic change. For instance they were nearly neutral on the notion that large scale irrigation could affect climate, but they agreed strongly with the idea that pollution could affect climate. In Table 3 below, 1 indicates strong agreement, 3 is neutral, and 5 represents strong disagreement.

TABLE 3

Weather has important effect on recreational activities	1.8
Weather has important effect on my livelihood	2.4
Volcanic eruptions affect climate	2.0
Pollution in the atmosphere affects climate	1.4
Clearing forests affects climate	1.6
Large scale irrigation affects climate	2.2
The climate of my state will change next 50 years	1.8
The global climate will change	1.6

Overall they felt that weather had an important effect on their recreational activities but were neutral concerning the effect on their work or livelihood. Perhaps the importance of recreational activities to these students explains why they believed that weather forecasts were accurate only half the time. Climate change was viewed as more likely by those who rated weather forecast accuracy higher, which suggests some relationship between belief in climate change and "respect" for weather science in general (Table 4). Most respondents believed that the factors mentioned in Table 3 can change climate, and that in fact, global climate will change and will probably affect their local area.

TABLE 4

MANOVA F-statistics

Test Variable	Significant variables (.01 level)	
Green House Effect	Science Hrs.	8.80
	Newspaper Hrs.	5.20
	Gender	5.25
Ozone Depletion	Science Hrs.	6.51
	Newspaper Hrs.	4.30
CFC's	Science Hrs.	21.58
	Gender	13.08
TRF's	Science Hrs.	4.79
	Gender	5.22
Climate Change State	Region of U.S.	3.14
	F'cast Accuracy	4.50
Climate Change Global	Region of U.S.	3.57
	F'cast Accuracy	3.00

5. SUMMARY

This survey of weather and climate perceptions revealed that these university students do in fact understand the potential for global climatic change. While they were in the first week of an introductory geography or meteorology class, they still had been exposed to some issues concerning climatic change. This exposure might have occurred earlier in their classroom education or through the media. The printed media seem to have had more impact on this particular population than the electronic media. The most important single source of information was science classes they had taken in college.

This survey also solicited information on the students' experience with weather (especially severe weather) as well as climate. Not only did this experience with severe weather show strong geographic patterns, but also seemed to color their perceptions of how climate might change weather in their locale. Thus climatic change is not only a "hot" topic in the scientific community, it is also a topic with which these students are familiar. Furthermore the familiarity extends to some of the vocabulary and mechanisms of climatic change. It was refreshing to know that many students do in fact view the world as a global system complete with feedback mechanisms and that concern with the ecological consequences of climatic change contributed to this knowledge.

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P1.37

YOU HAVE THE DATA. NOW WHAT?

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1. INTRODUCTION

With the rapid deployment of computers and telecommunications capability in the classroom, students and teachers have several ways of obtaining the latest meteorological and oceanographic data. However, just as the presence of lasers doesn't assure an illuminating physics activity, the availability of weather data does not automatically precipitate good teaching in meteorology.

The National Science Education Standards suggested by the National Research Council (NCSESA, 1994) offer guidelines for what all students must understand and be able to do as a result of their education in science. It is important to appreciate where the study of meteorology fits in under these Standards. There are eight categories of science content:

- Science as Inquiry
- Physical Science
- Life Science
- Earth and Space Science
- Science and Technology
- Science and Societal Challenges
- History and Nature of Science
- Unifying Concepts and Processes.

Traditionally, meteorology has not been granted an exclusive franchise in the K-12 curriculum. Instead, it has often been an elective or a unit within the broader study of Earth Science. The emerging Standards present both a challenge and an opportunity. The challenge is that meteorology might be viewed as just one part of one of the larger themes (Earth Science). The opportunity is that since weather and climate affect everyone and have profound influences on life, meteorology and related subjects are important niche players in every category of science education.

The study of meteorology should find its primary home in either the Earth Science or Science and Societal Challenges section. In fact, the latter category offers exciting possibilities for expanding meteorological education. Content standards have been proposed for each theme. Among the seven content standards established for grades 9-12 under Science and Societal Challenges are:

- Environmental degradation
- Natural and human-induced hazards
- Global changes
- Science, technology and public policy

The content standards under Unifying Concepts and Processes look equally interesting because all students should understand and be able to use the following concepts and processes:

- Systems
- Organization
- Form and function
- Interactions
- Change
- Measurement
- models
- Scale
- Diversity, adaptation and evolution
- Explanation

The broad spectrum of meteorological inquiry by scientists should translate into many niches for meteorological education in the K-12 curriculum. Since the major research and study tools in terms of graphics and data are available in the classroom in real time, this prospect is enticing.

2. METEOROLOGICAL ACTIVITIES THAT MEET THE GOALS OF THE NATIONAL SCIENCE EDUCATION STANDARDS

The availability of real-time weather data and graphics through services such as Accu-Data™ has effectively solved the problem that formerly hindered hands-on lab work in meteorology. There was no way to bring the huge atmospheric laboratory inside. A variety of ingenious and innovative experiments were developed over the years to get around this problem, but until very recently it wasn't possible to do a classroom investigation of a real weather situation.

However, the flood of information now available must be harnessed in ways that facilitate student understanding of atmospheric processes and how this relates to the student's life experiences. The present poster exhibit demonstrates how this is being done in today's classroom.

2.1 Elementary Activities

Using *Online with Accu-Weather*™ at the elementary school level, students and teachers start by exploring weather with their senses. Students are guided to discover that while much about our surroundings can be explained using one's senses, we need to do more if we are going to measure what's happening in the atmosphere, establish relationships and communicate our findings to others. Through activities that progressively expand the student's horizons, the class:

- uses cooperative learning techniques to describe the weather using the five senses.
- discusses and determines how to take standardized measurements.
- goes online with Accu-Data to relate local conditions to those at nearby and distant locations.
- learns how to use the language of the science of meteorology to report their findings.

In another activity, students examine a large storm and weigh the impacts on everyday activity. They determine the weight of snow to be cleared from driveways and walks. Through practical examples using appropriate mathematics for their level, students determine the costs and benefits of making the streets safe through salting and plowing. They discuss the negative impacts of these activities and weigh the consequences. Thus in one set of activities the student goes from learning to identify and appreciate how storms behave to working on real world problems that face today's public works officials and the taxpayers on a regular basis. An integral part of this is using online realtime weather information and integrating it with other components of the existing curriculum to bring relevance home to the student.

2.2 Secondary Level Activities

Students exploring meteorology in high school are challenged to use their learning in other scientific and mathematical areas to problems involving the atmosphere. For example, using *Online with Accu-Weather* (secondary edition), students search online for locations where various types of precipitation are occurring at sites where upper air information is observed. Students prepare and analyze temperature-height diagrams to determine at what levels precipitation is changing phase

In another activity, students determine the weight of ice on power lines and estimate at what point wires might snap. One exploration poses the issue of preparing for mountain hiking. How will the temperature and other conditions change with elevation? How can we find out about these conditions in real time? Can we forecast what's going to happen next?

3. Conclusions

For each class activity in the two editions of *Online with Accu-Weather*, we establish a set of objectives and propose techniques for reaching the objectives. The students use guided discovery techniques and employ real time weather data and graphics (through Accu-Data) to solve problems that interest them directly. Assessment activities are being developed to measure the extent to which the information has been learned and what steps need to be taken to enhance understanding.

A key component of this work is involving the teacher and student in the total process. Teacher training and instructions are provided so the teacher feels comfortable with the material and its presentation. A teacher's manual accompanies all materials, explaining various ways of exploring each topic and offering tips for solving various problems. The result is an experience for students in which they are doing real science the way scientists do it.

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P1.38

HIGH SCHOOL STUDENT BASED STUDIES EMPHASIZING THE IMPORTANCE OF METEOROLOGY IN UNDERSTANDING THE GLETSCHERVORFELD ENVIRONMENT: LOCATION - BODALSBREEN, JOSTEDALEN, NORWAY

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Introduction

During the months of June and July, 1994a joint expedition with students from the Lothian Region Schools (Scotland) and State College Area High School, (State College, PA) conducted field studies at the Bodalsbreen glacial valley in Norway. The Lothian Schools had made several earlier studies at this site. However, the 1994 expedition was the first to begin formal meteorological studies of the valley. A comprehensive set of instruments was installed so that local conditions as well as the consequences of large scale weather patterns could be investigated. Preparations for this study began in the fall of 1992; formal analysis of the data is now still in progress. Although the filed work did not go smoothly, the difficulties encountered in themselves provided the students with invaluable problem solving experiences.

Equipment and Preparation

Essentially right up until departure date new ideas were being debated and equipment being added to the inventory. All of the equipment used was donated by State College Area High School, the Department of Meteorology at The Penn State University, the Atmospheric Turbulence and Diffusion Division Laboratory of NOAA, the U.S. based Davis Corporation, the MJP Cornwall Company of Scotland, and the Royal Meteorological Society in Great Britain. Among the instruments and computers were: CR21X Campbell data-Loggers, a MACINTOSH power book, two IBM notebooks, two sets of pyranometers, Li-Cor radiometers, and a Davis Weather Station.

Before leaving the United States, the American team spent time with faculty, manuals, and books learning what about the environmental parameters to be studied. The learning experience was intensive , especially for those who hadn't previously studied meteorology.

Learning how to program and use the Campbell data loggers occupied much of the preparation time. Programming and learning how to do it in conjunction with the various computers introduced the team to the engineering aspects of science. Programming was difficult, but was mastered with the assistance of Penn State's Meteorology Department. Other challenges included constructing thermocouples for measuring soil and air temperatures. In addition general things, such as organizing wiring so that data would eventually appear in the correct spreadsheet locations provided the students with excellent "systems" experience.

To make sure everything would run properly, a mock weather station was constructed and operated at the rural home of one of the Penn State faculty. The Davis Station operated for a week; the Campbell units for a few days. One of last pre-evaluative tasks was testing the techniques required for recording the trajectories of neutrally buoyant balloons.

Norway

On arrival in Norway, the meteorology team split into two groups. One group went to the north and one to the south of the Jostedalsbreen icefield. These two glacial valleys were selected on the advice of Prof. Matthews of Cardiff University. These valleys were selected respectively for their north and south aspects. When the students arrived, the southern valley was still covered with more than three feet of snow with some places having only the ridges of prominent moraines appearing above the last winter's snows. Conditions made it impossible to do any field work. Thus, we decided to join forces with the group at the northern valley.

By the time the southern group arrived at the site, the north group had set up their Campbell logger and its associated equipment, and the Davis Instrument meteorological station north of the glacier on the eastern side of the river. Mounted on wooden masts and tripods, all the temperature sensors and pyranometers were up and running.

The south group redefined their research focus to investigate a snow covered surface adjacent to the glacier investigate a snow covered surface adjacent to the glacier so that the energy budget could be inferred for almost anytime of year (using percent snow cover).

Problems

Difficulties encountered by the students to get the instruments up and running were numerous. When the north group first set up its station on the lake, the Campbell unit got saturated. This required transporting some of the equipment back off the mountain. That night, using a camp hand dryer and instruction manual, the team learned how to repair in the field such a piece of complex electrical equipment. After being successfully dried care was taken so that it would never get wet again.

When the south group set their station up near the glacier, they were not aware of how fast the snow was melting. By the second day all the guide wires were useless and the pyranometer was no longer level. A few days later the team decided that a station here was impossible. Thus, it was dismantled and the equipment used at the northern site.

On the third day of the study, one computer crashed and we were not able to revive it. Bringing the southern group to the Bodalsbreen site provided thus also provided a critically needed computer.

After we thought that all of the start up problems had been solved, two of the channels in the CR21 (the north Campbell box) were not working and the soil moisture blocks not to be functioning. Since the Campbell Box up at the glacier had more channels (and less things being measured), we decided to switch them. Thus, both were reprogrammed. During this time a cold pelting rain refused to stop and fingers became quite numb. In order to make the exchange, and ensure for a continuous collection of data we imposed a limited time restriction. It took most of that time to walk to the station at the glacier. With everyone's help and hard work, the combined team accomplished their goal. Not all realized that they were on the way to dealing with yet more complications.

The Davis Instrument, which was supposed to operate from a simple 12 volt motorcycle battery had drained it by the third day, resulting in a loss of 16 hours of data. We replaced the battery and tried again, but again it had shut off by the next "service call". To solve the problem we eventually hooked it upto a new 12 volt car battery that the team had to carry up more than 3 km to the mountain site. This battery was also used to operate the Campbell station and the portable computers.

After all the equipment changes were made, we tried to download data for the first time. This turned out to be the highest set of obstacles to climb. Something was wrong somewhere and we could not get the computer to transfer the files from the CR21X. After two days of forgetting the manual, losing power on the computers, trying new things that still didn't make things work, and forgetting the link (which we never told our teacher about), we took everything back to base camp to figure it out. Several calls to IBM and PSU about the computer and the Campbell Box proved to be of little help. Finally the team retired to a dry, warm room at the campground and after three hours of research figured it out. We had neglected to include four lines in the program that enabled us to retrieve information. It was the best feeling in the world to walk out of the room, dump the equipmentin one of the vans and say "We got it, it's solved." From here on out, skies were blue and things went well. From about ten days of work, we would get five days of good data. Perhaps, a .500 batting average isn't bad!

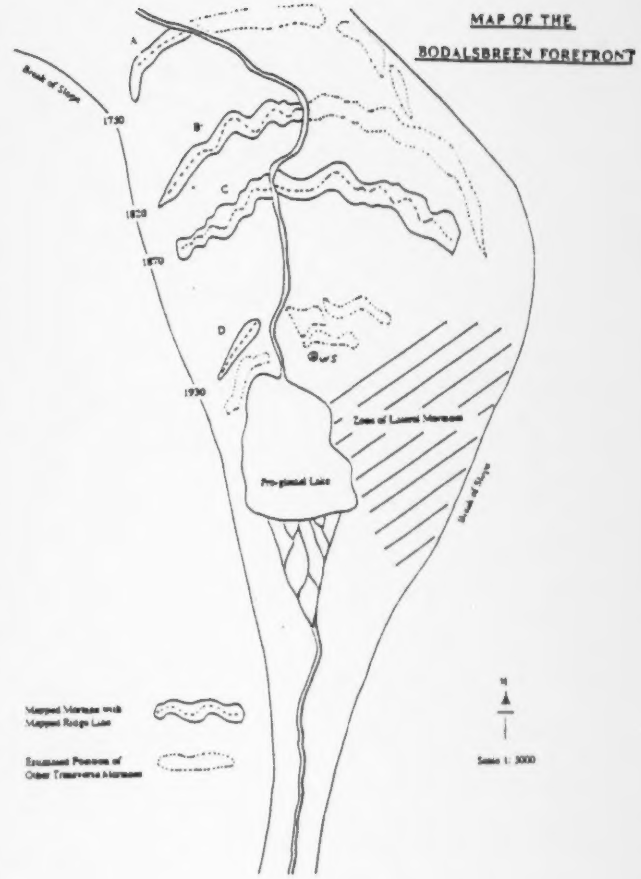
Significance of Meteorology

The Lothian Region Schools in Scotland provides selected students with this field experience every two years. Their work includes lichenometric dating moraine analysis, till fabric analysis, plant succession, and other related work. Although their studies have been successful in mapping and dating the otherwise obscure valley, its holistic study had not included a meteorological effort. Yet, scientists had reported the changing conditions produced by the weather would interfere with totally accurate research unless the environment is properly documented and studied. The meteorological study this year filled this need. Although the impact of weather was most easily seen in the biological study, in a climate sense it was also apparent in the geographical areas.

Student geographers spent an enormous amount of time drawing, mapping, and measuring moraines to provide accurate maps of the valley floor. Too the meteorologists, their extremely detailed and accurate maps might help to chart wind patterns over the moraines and determine how the katabatic winds affected the proximal and dismal slopes, or whether the moraines might create a boundary layer of air that was not affected by the katabatic winds. The till fabric analysis groups took the orientation and dip of stones in the moraine to provide an accurate picture of how the moraine was moved by the glacier. Using sieves to break down four kilogram samples of the moraines, the moraine analysis groups assessed stone size and roundness. These last two groups did most of their work below ground, but the impact of water is important to all the areas of geography. The rate at which the glacier is melting and increasing the discharge of the river, and the amount of rainfall can both cause rounding of stones and erosion of the steep sides of the moraines.

Regular point sampling along 300 metre transects on both sides of the meltwater stream which bisects the forefront produced massive amounts of data on plant types and local environmental conditions. This data is to be used to help explain plant succession ontothe clean area left behind as the glacier retreats. Norwegian glaciers have been in more or less constant retreat since the Little Ice Age of the eighteenth century.

This work reveals community rather than individual plants in succession. Closest to the ice and for 500 metres downslope primitive mosses and lichen has become established, followed progressively with distance from the ice by grass/herb plants, low shrub/small trees and eventually the mature birch forest. Work on dating individual surfaces using lichenometry will also produce ice front isochrons from which calculations can be made as to the rate of plant invasion for this particular elevation and this latitude. The significance of the meteorological investigations is perhaps most directly relevant to assisting work with plant communities. Of all the variable factors to be considered, the weather in the valley as a whole and even within localized areas is perhaps most important in explaining atypical occurrences. Of these occurrences, the effect of the cold dry katabatic wind on the different faces of the saw tooth moraines provided a startling example for all to see. The pools of night time cold air sit in the troughs between the moraines might be reflected in a detailed analysis of the vegetation. The drying effect of both the wind and reflected radiation from the ice surface contribute to many of the plants displaying xerophytic adaptations. All the trees in the valley are stunted and grow at an angle away from the glacier, though local sheltering produces larger straighter specimens. The new meteorological data now available is currently being studied with the hope that it will help explain some of these phenomena.



MAP OF THE BODALSBREEN FOREFRONT

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MICROMETEOROLOGICAL STUDIES IN THE BODALEN GLACIAL VALLEY, NORWAY INTERPRETATION OF THE ENERGY BUDGET OBSERVATIONS

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1. INTRODUCTION

During the past few years, concerns regarding the problems resulting from planetary global warming have been increasing. For example, significant increases in sea level could result from widespread glacial melting in the Antarctic, Greenland and other alpine areas. Significant changes in the sizes of glaciers are dependent not only upon the physical properties of their ice, but also upon seasonal and longer term weather-forced changes in the local climate. Study of the energy or heat budget is one method that allows us to estimate the total amount of energy which is exchanged between a glacier and the overlying atmosphere (Paterson, 1981). Downwelling solar and atmospheric infrared radiation will evaporate or melt glacial ice. Emission of infrared radiation from the glacier's ice surface will tend to retard the loss of ice. On an ice sheet, interpretation of a radiation or energy budget is much easier than in a location where the glacier is partially or completely surrounded by complex terrain. In this situation, different parts of the glacier are shaded at different times during the day, almost none of the ice surface may be horizontal and the glacial ice may include significant contamination by rock and soil fragments which will alter its radiative properties.

Prior research by students in the Bodalsbreen valley, Norway, included studies of the local vegetation located in this region (Gillespie's Expedition, 1992). Dixon's paper in the above referenced report indicated that interpretation of surface plant data could be greatly enhanced if information was available regarding local micrometeorological conditions including temperatures and winds. It appeared that limits on plant growth might be the result of temperature extremes, large variations in evapotranspiration rates, and mechanical stress produced by strong katabatic winds. All of the above plant growth-controlling phenomena also have the potential to control the rate at which the glacier's ice melts. We were, consequently, motivated to install a set of meteorological instruments that could provide measurements of the local radiation, temperature, and wind environment.

2. EXPERIMENTAL SITE

For the June 1994 expedition, the meteorological station was situated in the central part of the valley 0.75 km below the snout of the Bodalsbreen, one of many glaciers fed by the Jostedalsbreen ice field. From a meteorological perspective, this near-glacier site was located in extremely complex terrain. The Bodalsbreen is a saw-tooth glacier resting in a curved, U-shaped valley whose bearing is approximately north-south. The ridge of mountains to the east of the glacier is lower and less steep than the ridge to the west. The terrain at the station was irregular and quite rocky. Surrounding vegetation consisted primarily of lichens and moss.

3. FIELD INSTRUMENTATION

The recording instrument used for this study was a Campbell CR21X Micrologger provided by Penn State University. Signals from nine different sensors were sampled at 10 Hz, averaged to one minute and recorded. Various team members were responsible for programming the datalogger, calibrating and installing the sensors, and processing the recorded data. Different groups of the expedition team were then assigned the responsibility of interpreting the recorded field data. Post-experiment interpretation was greatly facilitated because all of the field-logged data was transferred via an optically isolated interface to PCs so that commercial software could be used for plotting and statistical analysis.

The first three input channels of the datalogger were hooked to copper-constantan thermocouples. The latter, constructed by several members of the expedition team, were made by twisting copper and constantan wires together, soldering them, and then sealing them with heat-shrink tubing to prevent water infiltration. The thermocouples in channels one and three were installed one meter apart, 5 cm beneath the surface to measure soil temperature. The thermocouple hooked to channel two was shielded from wind and solar radiation and installed at 2 m for measuring air temperature.

Several radiometers were provided by the NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). Two Quantum (Li-Cor, Inc.) radiometers, one up and one down-looking, were mounted on a horizontal plate and their signals connected to channels five and six. These sensors measure the photosynthetically active radiation from 400 to 700 nm. Although the plate supporting the radiometers was itself supported by a small tripod, we did our best to minimize obstructions to the field of view of the down-looking sensor. Two Eppley PSR (Precision Spectral Radiometer) radiometers, also lent by ATDD, provided an independent set of solar radiation flux measurements. The up-looking Eppley sensed the incoming global solar radiation, and the down-looking Eppley, the reflected or upwelling. The PSR sensors were also mounted on a flat plate and supported about a meter off the ground by a small tripod.

About a month after returning to the U.S., both the Eppley and Quantum radiometers were installed at Penn State's micrometeorological field site near Rock Springs, Penn. so that they could be calibrated against the sensors used there for continuously monitoring a variety of radiation variables.

4. DATA ANALYSIS

Interpretation of the complete energy budget at a given site requires knowledge of the following terms: incoming and outgoing solar and infrared radiation, the atmospheric and soil sensible heat fluxes, the latent heat flux, precipitation, and, if the surface is vegetated, the photosynthetic flux. The relevant equation for glaciers, as written in Paterson (1981), is

$$\Delta G + M = R + H - L_v E + L_f P$$

The following table in the right-hand column defines the symbols in this equation.

ΔG	**Rate of gain of heat for sensible or latent atmospheric heating**
M	**Heat used to melt snow and ice**
R	**Net absorbed radiation**
H	**Sensible heat**
L_v	**Specific latent heat of vaporization (2.5 * 10^6 J/kg)**
E	**Rate of evaporation from surface**
L_f	**Specific latent heat of fusion of ice (3.35 * 10^5 J/kg)**
P	**Precipitation rate of rain**

With the available instrumentation it was possible in our experiment to record only parts of the total budget. Neither eddy correlation-capable nor sufficiently sensitive humidity sensors were available to measure the sensible and latent heat fluxes. Even if adequate sensors had been available, interpretation of data from them would have been problematic for a location having such complex terrain. The problem is basically one of whether or not the required Monin-Obukov similarity law assumptions can be satisfied (Arya, 1988). Precipitation was irrelevant to our studies as none occurred on the days of interest. Although the expedition went to Norway with the intent of making the measurements on the ice, conditions on the glacier prevented us from safely doing so. Consequently, we decided to focus our interpretation of the available radiation and temperature data on examination of the effects of the surrounding, complex terrain on the energy input to the glacier's valley.

In the following figures, 1 through 7, we show examples of the recorded micrometeorological data. These figures include the temperature readings acquired from the thermocouples, values from both types of radiation sensors, and the albedo (calculated using the values from the Quantum radiometers). All of the graphs' x-values represent minutes from an initial time. Temperatures are in °C and radiation values are in W/m^2.

From figure 1, it is apparent that the topography of the surrounding area is affecting the energy input to the valley. A normal curve for the soil temperature over time would rise smoothly and logarithmically, and would fall in an inversely exponential manner (according to Newton's Law of

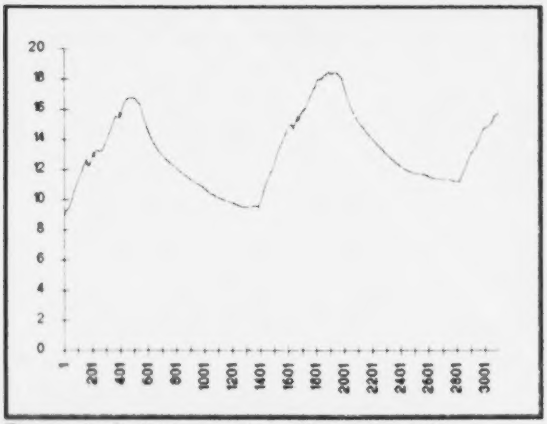

Figure 1: Soil temperature (thermocouple)

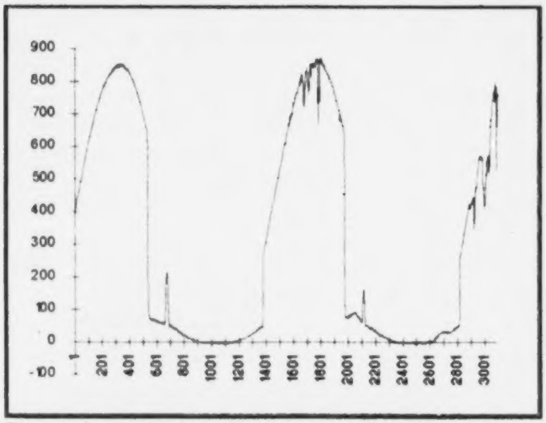

Figure 3: Up-looking Quantum radiometer

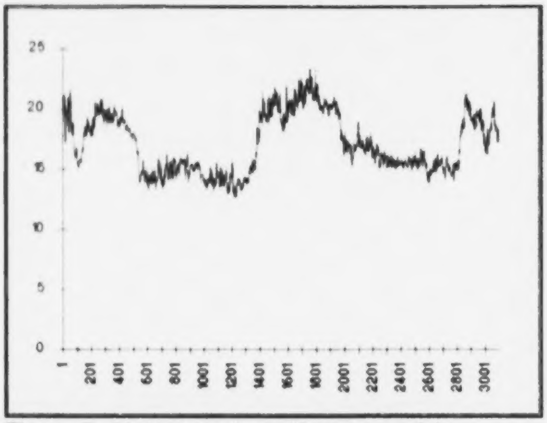

Figure 2: Air temperature (thermocouple)

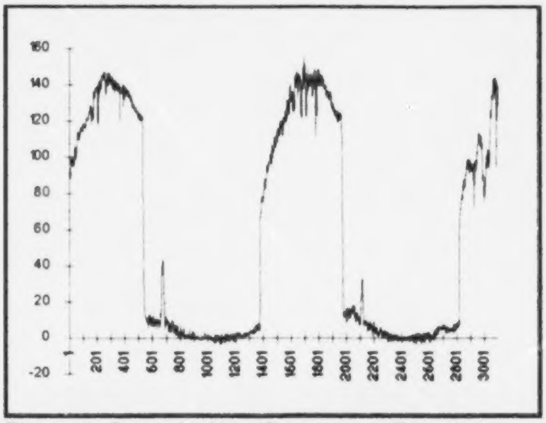

Figure 4: Down-looking Quantum radiometer

Cooling). However, the data acquired by our instruments rises irregularly, indicating that the sun's radiation was at least partially blocked several times during the heating process. The temperature falls more smoothly, and thus closely resembles an ideal model because the surrounding terrain will have a lesser effect on the soil's emission of longwave radiation (resulting in heat loss). The air temperature (figure 2) is affected by both sensible heating by the soil and the glacial, principally katabatic, winds. Although the temperature changes are much more complex, they do follow a basic diurnal heating pattern.

Both the incoming and outgoing solar radiation, as measured by the Quantum radiometers, verifies the soil's partial exposure to the sun. At around 6:15 a.m. (daylight saving time) the graphs (figures 3 and 4) rise sharply, showing that the sun had just risen over the edge of the mountain ridge on the eastern side of the valley. The jagged irregularity during the daylight hours shows that clouds intermittently blocked the sun's radiation from the instruments. At around 4:15 p.m., the radiation dropped sharply, showing that the sun had reached the edge of the mountain ridge to the west. However, there is another peak later in the day, around 6:00 p.m. This peak is very sharp and the duration of this increase in radiation is very short. As this peak to occurred at the same time every day, it is apparent that it was caused by local topography. This peak of radiation probably was the result of the sun's having broken through a break in the mountain ridge. Calculations of the sun's precise path with respect to the topography of the surrounding area are in progress.

The graphs of the data from the PSR radiometers (figures 5 and 6) resemble those obtained with the Quantum radiometers. However, the down-looking PSR appears to measure a maximum value that occurs 3 times daily, slightly exceeded before noon. Unfortunately, these measurements may have been noticeably affected by our method of mounting the instruments. The graph reaches its upper limit quickly

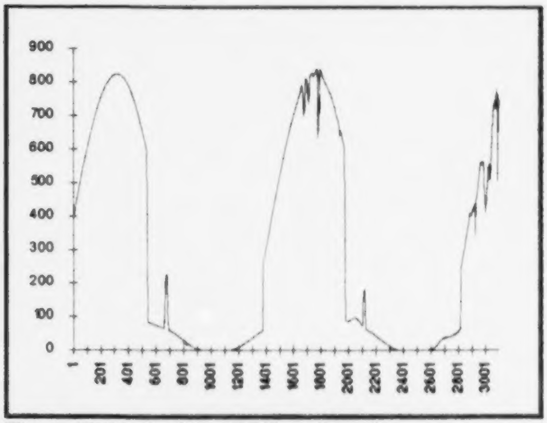

Figure 5: Up-looking PSR radiometer

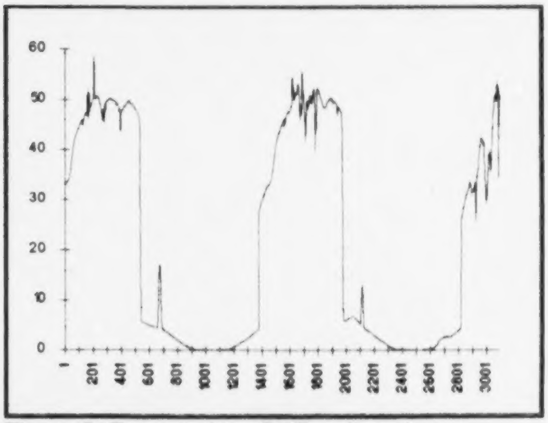

Figure 6: Down-looking PSR radiometer

and remains there until falling as the sun's radiation decreases much later in the day. This could have been the result of the metal mounting plate shading the ground beneath the sensor from radiation. The three small peaks in each daytime curve of the graph most probably represent the times that the sun was shining between two of the three tripod legs supporting the sensor's mounting plate. The down-looking Quantum radiometer seemed to experience this effect to a much smaller degree.

The last graph (figure 7) shows the albedo of the moss covered surface over time, with the night-hour values deleted. The graph varies somewhat throughout the day. The variations in the curve illustrate that the albedo is somewhat sun-angle dependent. The average albedo, calculated from the values shown in the graph, is about 0.19.

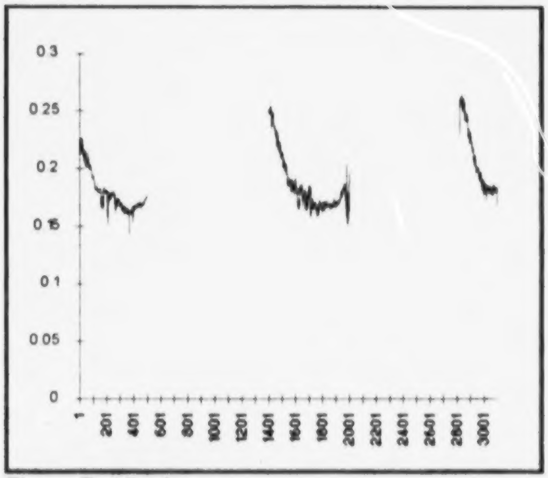

Figure 7: Albedo

5. CONCLUSION

If one attempts to take into account the complex terrain and naturally varying albedos of a glacial valley, analysis of the energy budget is difficult. The presence of local katabatic winds also can cause considerable temperature changes in the soil.

This field study provided us with the data necessary to begin to examine the effects of a complex topography on the amount of energy available to a glacier. The dataset may also be of value to future micrometeorological, biological, and geographical experiments.

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P1.40

Studies of Winds in the Bodalsbreen Valley in Norway

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Introduction

Prior research by students in the Bodalsbreen valley, Norway, included studies of the local vegetation located within this region (Gillespie's Expedition, 1992). Dixon's paper in the above referenced report indicated that interpretation of surface plant data could be greatly enhanced if information was available regarding local micrometeorological conditions including temperatures and winds. It appeared that limits on plant growth might be the result of temperature extremes, large variations in evapotranspiration rates, and mechanical stress produced by strong katabatic winds. All of the above phenomena strongly depend upon the diurnal cycle of heating and cooling in the valley.

Experimental Objective

One purpose of the studies undertaken by students from State College High School was to determine properties of the local katabatic flows. The times at which they began and ended and their speeds were of particular interest.

Pre-Expedition Preparations

Before leaving for Norway, the experimental methods which were expected to be used were tested in an open field near State College in which drainage winds, a form of weak katabatic flow, were regularly observed. The purpose of these experiments was to verify that video recordings of the motion of neutral density balloons and interpretation of their trajectories could be used to measure the speed and direction of a local katabatic flow. In addition, an anemometer and wind vane provided by the Davis Instrument Company was tested to confirm that it's threshold velocity was sufficiently low to be usable in a situation of this type. At the same time modifications were made to the instrument's wind vane to insure that there were no frictional impediments to it's movement.

Field Measurements

At the Bodalsbreen site the Davis instrument, which also included temperature, humidity and pressure sensors, was installed in the central part of the valley 0.75 km from the snout of the glacier. A small glacial lake was about 200 meters west of the station. At the same location, a second set of meteorological instruments was installed and connected to a Campbell CR-21X datalogger. This set of instruments included air and soil temperature sensors and radiometers for incoming and outgoing solar radiation. Temperature sensors were installed 10 cm beneath the surface, essentially on the surface, and one and two meters above the ground.

Data from each of the Davis Instrument sensors was sampled at sec. intervals and averaged to five minute periods. The signals recorded with the Campbell datalogger were sampled at 10 Hz and recorded every second. Observations were recorded without interuption from June 30 through July 5.

On-site Wind Experiments

On-site conditions in Norway proved to be very different than expected. Irregularities in the surface and the speeds of the wind were both much greater than had been anticipated. Thus the team decided to release mylar balloons at three different locations. For the first experiment on an overcast day the release locations were aligned across the valley floor about 250 meters in front of the glacier. About 20 balloons were released. Their motion was recorded by video cameras which had been set up to look down and across the valley.

The second balloon experiment was situated about 1 km from the glacier on the distall side of a predominant moraine. This was an optimal day for a katabatic flow experiment, as the skies were clear. Since katabatics are winds driven by differences in pressure, it is necessary that solar radiation is available to heat the land, and, in turn, the air. The warmer air on the valley floor is replaced by the colder, denser air flowing from the glacier.

The third and final release was accompanied by a smoke bomb. Started on the proximal side of another predominant moraine, approximently 1.5 km from the glacier, the smoke bomb was included in this experiment to help define the air flow patterns over the moraines.

The trajectories of the balloons could be recorded on film for only a few minutes because the wind speeds were so high, 25 kph and higher. Due tothe limited time on site only three experiments were performed.

Observations and Interpretation

As indicated above the actual experimental conditions were very different from what was expected. Average winds were about 25 kph with gusts of up to 64 kphr.

During the first balloon release, a down valley wind starting approximately four meters above the valley floor was observed. Any of the balloons carried by this wind that ended up near the mountainside were then caught in another wind, carried up the side of the valley, and then back up the valley in a return circulation. Any balloons that were within four meters of the surface remained stationary.

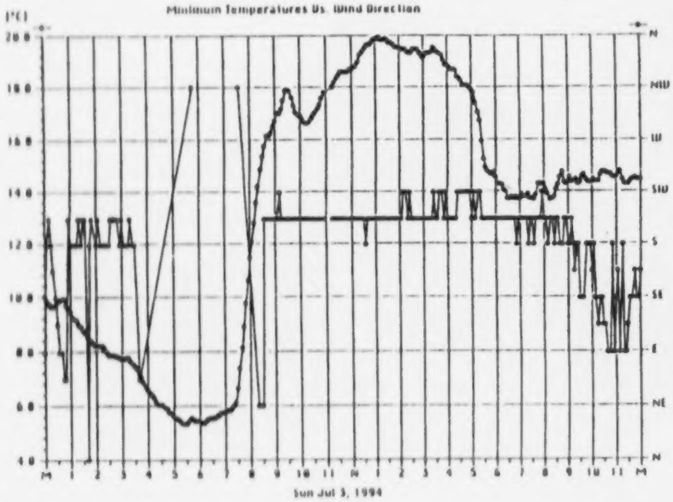
The second balloon release, started on the distall side of a moraine, produced similar results with one difference. After skipping over several of the moraines, some of the balloons were entrained into the katabatic wind and transported down the valley. As before, those balloons carried to the sides of the valley were caught in an upward flow, apparently a valley wind. In this experiment several of the balloons ended up being trapped in eddies between moraines.

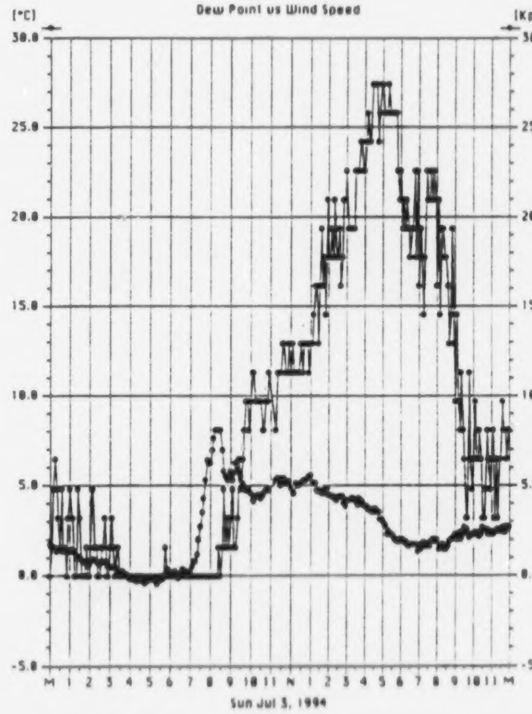
During the third experiment, the balloons floated over the first moraine and down into the adjoining distall plain. Upon reaching the following moraine, they were entrained into the katabatic flow. The smoke, however, dissipated too quickly to be of any use. During this last experiment, two of the balloons again were captured by the valley wind and proceeded up the mountainside.

As it turned out, the wind data recorded using the Davis instrument was critical to our understanding of developement and evolution of the katabatic flow. We had expected that the katabatic winds would be primarily nocturnal. The anemometer data showed that the winds started each day, early in the morning, around 9:00 am. Wind speeds then steadily increased until about 7:00 pm. Thereafter they slowly decreased until midnight. It was between midnight and 9:00 am when the minimum wind speeds were recorded, between zero and about five kph. When the wind speeds were high, the direction was generally south southwest, the appropriate direction for a katabatic flow at this location.

Conclusion

The observed katabatic and valley winds were far more complicated in character than originally expected. Our ongoing studies of the available field measurements are now being directed toward interpretation of a wind field in a location having complex terrain and stably stratified layers. Thus we are now also using the available temperature gradient and humidity measurements to try and infer the source locations for the winds observed at various heights above the surface and along the valley walls.





P1.41

LOOKING AT EARTH FROM SPACE

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1. THE MAPS-NET PROJECT

The National Aeronautics and Space Administration (NASA)-sponsored Maryland Pilot Earth Science and Technology Education Network (MAPS-NET) project was launched in 1991 to strengthen pre-college teachers' understanding of Earth system science and to enhance their existing curriculum. Direct readout from environmental satellites (the ability of users on the ground to obtain data directly from the satellites) was selected as the cornerstone of this effort to provide teachers with an accessible, inexpensive, and exciting tool to engage students' interest. Emphasizing meteorology enables participants to understand direct readout imagery, and serves as a foundation for studying the Earth system. The project now includes elementary through high school level math and science teachers, who are using their MAPS-NET training and direct readout technology to enrich learning for students at all achievement levels.

2. MISSION TO PLANET EARTH

Space exploration has changed the way one views Earth. Only from space can changes affecting the entire globe be seen. Images from space vividly illustrate Earth as a single entity composed of atmosphere, land, and water.

NASA's Mission to Planet Earth (MTPE) is an integrated, sustained, and comprehensive program to observe, understand, model, and predict global change. These activities will provide the scientific basis for informed policy decisions related to our influence on the global environment. Although many issues of global concern have been studied for decades, their impact has only recently been considered in terms of affecting the complex, single system that is Earth.

Part of the challenge of MTPE will be to prepare knowledgeable and responsible scientists, citizens, and decision makers. Engaging students in MTPE is critical. Fortunately, evolving science education goals and standards emphasize the importance of science curriculum that is relevant to student's lives; involves students in exploration, data gathering, and experimentation; and engages students in higher-level thinking skills. Many schools are reinstating Earth system science classes.

3. SATELLITES IN THE CLASSROOM

Environmental satellite imagery is an excellent vehicle for studying Earth system science. Using a classroom ground station to obtain imagery involves students in a complete and continuing science experience. In addition to utilizing current technology, acquiring their own data, working with a global perspective, and having significant control over research parameters, direct readout enables many students to be captivated by science.

To make direct readout successful in the classroom, technology must be installed, used, and the data integrated into the curriculum. The best way to make those three things happen is to ensure that teachers feel confident using the technology and the imagery. To meet those goals, a MAPS-NET graduate-level course was developed for Maryland pre-college science and math teachers. The course materials are being published by NASA, as a series, entitled *Looking at Earth From Space*.

The course content and publications are a collaborative effort of the WT Chen & Company-lead MAPS-NET team and the MAPS-NET academic host--the Department of Meteorology, University of Maryland at College Park. Additional materials and review were contributed by the MAPS-NET teachers (who teach grades 4-12), scientists, technologists, and other educators.

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The training materials are appropriate for teachers or high school students, the classroom materials have been created to respond to a variety of classroom needs, the lesson plans are equally useful for ground station users or people who get their imagery from the Internet. The introductory and technical publications are appropriate for parents, faculty, students, and administrators.

4. THE PUBLICATIONS

A variety of lessons have been learned throughout the MAPS-NET project, including the importance of accessible, understandable information about a variety of relevant topics. Six documents were developed in response to MAPS-NET teachers' needs. Those documents are being published and distributed by NASA to serve educators nationally and internationally. The series entitled *Looking at Earth From Space* includes the following documents.

1. *Introduction to Direct Readout* booklet introduces the topic and provides an overview of the educational application of direct readout.
2. *Guide to Direct Readout Equipment and Vendors* provides information about set-up in addition to listing components and equipment sources.
3. *Glossary of Terms* describes terms and acronyms for meteorology, direct readout, Mission To Planet Earth, NASA, the National Oceanic and Atmospheric Administration (NOAA), global change, etc. Diagrams accompany many of the terms.
4. *Teacher's Guide to Global Change* introduces some of the critical issues for our planet and includes classroom activities.
5. *Direct Readout Training Manual* is a synthesis of the meteorology and technology covered during the MAPS-NET graduate course. The inclusion of sections on satellites, orbital elements, resources, etc. provides a comprehensive approach to understanding remote sensing, environmental satellites, and using direct readout.
6. *Teacher's Guide to Direct Readout* is a compilation of lesson plans developed by MAPS-NET teachers, accompanied by satellite imagery, explanation of the imagery, and background information.

Looking at Earth From Space publications may be obtained, without charge, from your nearest NASA Teacher Resource Lab (TRL). The publications are printed in black and white to encourage copying and distribution to the broadest possible audience.

5. LOCAL SUPPORT

The MAPS-NET approach incorporated contributions from many sources to ensure that participating teachers, who have impressive but often diverse backgrounds, received the support, resources, and/or information critical to their classroom success. Experts from NASA, NOAA, the University of Maryland, and Maryland classrooms contributed and reviewed the materials. Representatives from the Maryland Department of Education and our participating teachers helped structure the course content and project goals so they align with both state and classroom requirements. Members of Maryland industry contributed advisory skills, served as mentors and speakers, and contributed funds to purchase Earth stations for schools. The Maryland Space Business Roundtable served as bursar for a fund-raising effort to equip schools state-wide. The Dallas Remote Imaging Group (DRIG) provided technical support, from setting up antennas on school roofs to replacing software and repairing equipment. The media, both print and television, made people aware of this innovative approach to learning.

6. DISCOVER EARTH

Experience and knowledge gained through the MAPS-NET project are being applied to the development of a new MTPE education project entitled *Discover Earth*. Successful features of the MAPS-NET project will be incorporated in this broader-based approach to teaching Earth system science. Contact the author for additional information.

P1.21A

FORECASTING THE FUTURE: TEACHING ABOUT GLOBAL CLIMATE CHANGE

A CLASSROOM CURRICULUM, WORKSHOP, AND CLASSROOM CONSULTATIVE SERVICES FOR TEACHERS

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The prospect of global climate change is a sobering one. It challenges today's citizens and decision-makers, and is likely to demand continued consideration well into the future. How will today's science students come to understand the nature - and the limitations - of science's power to predict and prevent impending climate change? Researchers from the NSF Science & Technology Center for Clouds, Chemistry, and Climate at UCSD have joined educators from the Stephen Birch Aquarium-Museum at UCSD's Scripps Institution of Oceanography to develop a new curriculum that explores how scientists study changes in our planet's health. The curriculum integrates evidence from the fields of paleontology, chemistry, physics, biology, meteorology and others to describe in non-technical terms the processes of global climate change research. Student activities parallel scientists' activities, bringing classroom studies into the world of science with via up-close and hands-on investigations.

Scripps Institution of Oceanography sponsors workshops for teachers try hands-on activities whereby students use scientists' investigative instruments and methods. Participating teachers also receive a "TravelLab" of equipment and materials, including pictorial slides, classroom computer software, and videotapes, useful in implementing the curriculum. In addition, staff from the aquarium-museum offer teachers in-class consultation and follow-up. Overall, Forecasting the Future strives to provide all resources needed by teachers of fifth-twelfth grades to:

- acquire and transmit to students an accurate informational overview, organizing concepts, and vivid examples with respect to this topic;

- learn and implement classroom activities that parallel methods used by scientists in the field and in the laboratory;

- engage in systematic electronic communication with scientists, science educators, and each other to chronicle progress on curriculum implementation; and

- assist in identifying factors that create effective, site-independent classroom environments for the study of global climate change.

P1.32A

AN INTERDISCIPLINARY CONNECTION FOR SCIENCE, MATH, ENGLISH, SOCIAL STUDIES AND HEALTH IMPLEMENTED BY THE USE OF THE INQUIRY METHOD

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Tropospheric ozone is caused by the formation of photochemical smog production which causes damage to plants and animals by effecting the atmosphere's oxidation capacity. Tropospheric Ozone can cause damage as seen in the respiratory systems of animals, promoting scar tissue formation and cell damage by oxidation(Rasumovskii and Zaikov, 1984). Approximately 90% of all ozone is found in the stratosphere and 10% in the troposhphere(Finlayson-Pitts and Pitts, 1986). Whereas ozone found in the stratosphere is considered 'good ozone' and is safe for the environment, ozone found in the troposphere, our immediate atmosphere, is considered 'bad' ozone and can be very dangerous to living organisms.

Ozone, molecule made of three oxygen atoms, was discovered in 1839 by Professor Christian Frederick Schoenbein at the University of Basel, Switzerland(Fishmann, 1990). The ability of Ozone to readily give up an oxygen molecule makes it a powerful oxidizer. Schoenbein utilized the reactivity of ozone to measure its presence and prove that ozone can be detected by using a mixture of potassium iodide and corn starch on filter paper.

The Social impact, policy and legislation concerning the Clean Air Act, along with the history of ozone measurements in the United States encourages the teacher to make the interdisciplinary connection. The inquiry method of science, english and other disciplines allows the student and teacher to discover what can be accomplished by using 100 year old method of detection. Math, english, health and social studies work together to discover how tropospheric ozone has impacted our lives. Combining the unique idea of Schoenbein's ozone detection with interdisciplinary connections helps to bridge an understanding from teacher to student to encourage learning, communication and a responsibility for our environment.

FOURTH SYMPOSIUM ON EDUCATION

PAPERS IN JOINT SESSIONS

(edged in grey)

PAGE #

J1: K-12 EDUCATIONAL PROGRAMS (J1) 1-25
(Joint with 24th Conference on Broadcast Meteorology)

J6: NEW TECHNOLOGIES FOR THE CLASSROOM (J6) 1-58
(Joint with 11th Conference on Interactive Information and Processing Systems [IIPS] for Meteorology, Oceanography, and Hydrology)

J1.1

MAP READING AND INTERPRETATION SKILLS DISPLAYED BY HIGH SCHOOL FRESHMEN

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1. INTRODUCTION

Reading maps is a fundamental skill required of most students in the precollege educational curriculum. Map reading is really a diverse set of several skills. These skills must be combined and applied to extract meaning from a map (a complex information document). Maps are frequently found in science and non-science courses as they allow for the transfer of large amounts of information in a concise format. This is particularly the case when students are required to examine weather maps in the science classroom. However, not much Piagetian research (research involving student reasoning and content understanding) has been done in this very important area of learning.

The purpose of this paper is to (a) review current Piagetian literature on this topic, and (b) report preliminary results associated with specific map reading skills found in ninth grade earth science students. The information presented in this paper is designed to aid teachers in constructing age appropriated classroom activities involving maps and mapping concepts.

2. BACKGROUND

During the first half of this century, research was conducted by Jean Piaget (1964, 1970) into how children learn about the world around them. Piaget first recognized that normal childhood development is marked by a growth in understanding and reasoning abilities. He identified and described sequential stages of development that are successive, ordinal in nature, and consistently found in every society studied to date. Piaget's theories and research are important to the entire scientific and educational community because they provide insights into the growth and development of logical thinking.

Piagetian research is clinical in nature. It seeks to understand how children develop an understanding of the world around them, and how an individual's content understanding is linked to reasoning processes. Reasoning processes are observed and measured when specific Piagetian tasks are administered during clinical interviews. The focus of these interviews is to determine how a subject reasons to solve Piagetian tasks and how content understanding is utilized.

Piagetian research is different from typical content understanding research. It provides a developmental framework that includes reasoning ability to identify and understand the widespread problems of scientific competence both in our schools and in our society. It also provides a foundation for developing appropriate curriculum and suitable classroom activities.

3. EXISTING RESEARCH

Piagetian-type studies of how children develop an understanding of map reading are limited, aging and revealing. Cheek and Muir (1983), studied elementary mapping experiences of children in the Concrete Operational stage of development. They developed and tested a model based upon seven mapping skills (symbols, perspective, direction, distance, location, scale, and relief). Each of these mapping skills was defined by an appropriate question, each had a companion mathematics skill, and a related Piagetian assessment task.

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They found that "even under optimal research conditions, some [mapping] skills appear impossible to teach to students below grade seven." They further elaborate, "Skills which are not appropriate to the elementary grades include work with map projections, understanding of time zones, use of longitude and latitude, comparison of different map scales, and interpretation involving two or more maps."

The concept of territoriality (recognizing and understanding map regions i.e. state, nation) are "rarely acquired before ages 11 or 12" (Renner, 1951). The concept of city, however, is more readily acquired if students have actual experience with that area.

Richards (1983) argues that teachers need to tailor instruction to the child's experience. He suggests that mapping activities be structure within the curriculum in such a away as to complement the child's stage of development. He further advocates that the introduction of learning activities about maps and mapping concepts be intellectually challenging requiring students at each developmental stage to be pushed to the limit of their experience base. Some of his suggestions are identified in the classroom activities section found in figure 1.

4. CURRENT RESEARCH

For the purpose of our study we defined formalized mapping skills as (a) constructing a profile map, (b) computing gradient, (c) drawing isolines, and (d) recognizing field changes. This author suggests that these mapping skills are essential and appropriate skills to derive meaning from any type of map that a student may need to read. This research effort focuses on two essential questions; Which formalized mapping skills can a student with concrete operational thinking abilities reasonably be expected to master? and Which of the formalized mapping skills can be mastered by Formal Operational thinkers only?

One hundred and seventy six high school freshmen were tested for stage development via the Raven's Test Of Logical Operations (Raven, 1973). Results were used to classify students as either Concrete Operational or Formal Operational. All students were also administered a mapping examination that tested their ability to perform each of the formalized mapping skills previously specified. Data from nineteen subjects classified as Concrete Operational and 19 subjects classified as Formal Operational were then randomly selected for analyses. Analyses consisted of testing for significance the observed correlations between specific logic skills (which serve as the defining criterion measures for Piagetian Stage) and the specified formalized mapping skills found on the mapping skills examination. For $\underline{N} = 38$ and $\alpha = .01$ the test statistic was distributed $t_{30:\,.005} \geq 2.750$.

5. RESULTS

The criterion measure (correlational logic operation) is only associated with Formal Operational thinkers and was found to be significantly related to two mapping skills (isoline construction and recognizing a change in field pattern). The other two mapping skills (gradient computation and map profile construction) were not significantly related to Formal Operational thinkers and were thus attainable by both Concrete and Formal Operational thinkers alike.

6. DISCUSSION

The preliminary results of this investigation would tend to add strength to the argument that all but two of the specified mapping skills should be attainable by middle school students in the Concrete Operational stage of development. Therefore, it would seem appropriate that most students well into (experienced Concrete thinkers) the Concrete Operational stage should with sufficient teaching be able to use most mapping skills presented to them. It appears that only the isoline construction task and the recognition of changes in field patterns would be unattainable

DEVELOPMENTAL GUIDELINES FOR INTRODUCING MAPPING SKILLS

by

Dr. Paul J. Mroz

Piagetian Stage Of Development	Approximate Age Range	Developmental Goal	Classroom Activities
Pre-Operational	2 - 7 years	1. Understand Object Permanence 2. Develop a two-dimensional perspective 3. Encourage the development of an alternate view or perspective.	1. Viewing & drawing objects from different perspectives* 2. Provide experiences with 3 dimensional models* 3. Encourage play with building blocks to construct 3 dimensional objects.* 4. Recognize & locate familiar objects on aerial photographs*
Concrete Operational	7-11 years	1. Developing two & three dimensional perspectives (area & volume). 2. Transform two dimensional representations into three dimensional representations.	1. Make diagrams & pictures of familiar places.* 2. Construct area models of familiar locations & settings* 3. Use aerial photographs to design area models from an altitude perspective. 4. Introduce cardinal (NEWS) directions, simple scale, gradient, profile and distance measures. 5. Construct simple coordinate grid systems.
Formal Operational	12-13 + years	1. Develop the use of map symbols, proportions, and mathematical representations of map features. 2. Use logically abstract representations to depict field quantities.	1. Provide students with experiences that involve the use of map symbols, ordinal directions, (0, 45, etc.) map scale & proportions, distance scale & measure, gradient, profile, latitude & longitude, relief, isoline construction, and examples of change in field.

Figure 1. Developmentally Appropriate Guidelines for Introducing Mapping Skills. *After L. Richards, 1983.

by Concrete Operational thinkers. This, is not totally unexpected as most teachers who have tried to teach these two mapping skills to students find considerable difficulty in getting the 'message' across. The findings of this study would indicate that it is best to wait until students have attained Formal Operational thought patterns before attempting to teach them how to construct isolines and recognize changes in field patterns. This finding does partially explain why many students have such a difficult time understanding the isolines (typically isobars and isotherms) patterns found on all types of weather maps. It also suggests that students don't understand changes in isoline map patterns. This would indicate that simply showing students weather maps with isolines on them is not sufficient to convey meaning. Map changes must be accompanied by weather symbols which convey sufficient information to make the map reading exercise a meaningful activity.

Developmentally appropriate guidelines for teaching mapping to students is provided in Figure 1 of this paper. It is a compilation of all the traceable Piagetian-type research on this topic to date. Teachers are encouraged to find or create methods of presenting each of the mapping skills in such a way as to enhance the transfer of meaning and understandings to all students. Here, the key element is to provide mapping instruction that builds concretely upon the foundation of experiences the child brings to the learning situation.

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J1.2

EDUCATIONAL PARTNERSHIPS LEADING TO THE PROMOTON OF STUDENT CENTERED METEOROLOGICAL FIELD STUDIES IN A GLETSCHERVORFIELD ENVIRONMENT.

JOSTEDALEN, NORWAY

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Selected schools in Scotland have had a long history of partnerships with industry Specifically, the James Gillespie's High School has had a program of outreach to industry since its inclusion with the BP Link Scheme in the 1960's. The Scheme's objective is to increase the mutual understanding and partnership of education and industry. Incumbent to the scheme is the need to stress the initial considerations of science and technology as they relate to the industrial community.

Nine secondary schools in the Lothian Region are involved in the Link Scheme. In 1986, James Gillespie's entered a new partnership that enabled the schools to embark on curriculum innovations thatresulted in a fully interactive centre of technological excellence. These partnerships enhanced teaching within the curricular areas prescribed by examination boards and other outside agencies. One of the desired outcomes was to prepare a student population in field experiences associated with the use of industry specific equipment, data collecting, and data analysis. This objective would not only prepare those studentsgraduating from school to be more easily assimilated into the industrial community, but also to offer some experiences for those seeking higher levels of education. The Norway Expedition described in this paper is an example of one of the successful field studies.

Sponsorship from industries in Scotland has played an important part in meeting the financial commitments of the Expedition. Industry also provided technical assistance and a very positive learning environment. Surveyors, engineers, technicians from industry, and learned members of the university and professional societies were placed at the disposal of the Expedition both in training the students , answering their questions, and making equipment available for student use. As the Expedition program continued to develop, the venture had the blessings of education authorities in three countries who endeavored to ease the administrative difficulties in organizing the trek, and provided support with expertise and formal blessings.

The theme of partnerships in education is relatively new to the American science education community. Although it has been popular in some urban centers of the United States, the 60% of the country that can be considered suburban or rural has experienced limited familiarity with this concept. Partnerships with federal, industrial, and collegiate organizations increased in the last decade as the United States education system reeled from the accusations that the performance of the nations's youth was appalling inthe disciplines of science and mathematics. A lack of public funding coupled with the reticence of the professional educators to address some newer and more innovative means of confronting the problems, prompted members of these organizations to explore avenues that would permit them to become involved in the improvement of the student outcomes in critical subject areas.

The United States government has long been active in funding programs designated for improving public education. Since Sputnik, the NSF has been actively supporting teacher enrichment programs. However for the past two decades, their funding has been limited and other sources have had to initiate teacher or student training programs. More recently, industry has taken an active role. If the United States and Scotland are to remain competitive in the world market, they will require a more educated work force that can adapt to change and comprehend the increasingly sophisticated working environment. Colleges and Universities also recognized that they too would have to become more active in pre-college programs associated with mathematics and science if they were to maintain a pool of prospective majors in these disciplines.

Too often talented young men and women eschewed the disciplines of science and mathematics because of the perceived rigors of these courses of study. In many instances, their association with mathematicsand the physical sciences involved interaction with dull and unimaginative curriculums. Students seldom are offered the opportunity to become part of the energetic and invigorating field studies that often precede research and discovery associated with these disciplines. Thus they often opt for the more glamorous disciplines of life sciences or the less "boring" disciplines associated with the liberal arts. Members of the teaching profession, especially those associated with the sciences often leave college with the same impressions. Those who never participated in field studies, tend to design their curriculums with units designed to emphasize information acquisition rather than as a true problem solving environment. The mastery of subject matter is always emphasized over the thrill of discovery. If as nations we are to improve the student outcomes in science and mathematics, we must instill in the teachers the "thrill" of science rather than the "content" of science.

A series of circumstances evolved that permitted two teachers from different countries to participate in an innovative and invigorating expedition that would not only allow them to once again experience the thrill of science, but also to share this experience with students. Often the negative publicity associated with the public education system leaves members of industrial, professional and collegiate communities with the impression that public school teachers confine their professional activities to the daily rigors of preparation and teaching of curricular materials. On the contrary, many teachers are actively engaged in turmoil of publications, communication, and for some, actual research. As with our associates in the collegiate world, often we seek to communicate with other members of the profession the successes of our efforts. Last summer both authors of this paper were presenting at an international conference that was sponsored by the American Meteorological Society and the Royal Meteorological Society. While at the conference, discussions occurred concerning the embellishment of a successful field studies program already in place on the European continent. The commitment of the AMS to public education through the Atmospheric Education Resource Agents and their development of successful educational programs initiated discussions of how meteorology might be more rigorously involved in a holistic field study already in the planning stages for European students. As a result of these discussions, commitments were made to the program by agreeing to become part of the instructional team. In designing the meteorology component, it was necessary to define a rational for an increased emphasis associated with the physical sciences and then to determine what type of research would both meet the needs of the established field program and the potential needs of participating students.

The first partnership was between the educational models of Scotland and those of the United States. This required communication between the expedition leader (a teacher of geography) and an a American science teacher (a teacher of earth systems sciences) concerning prevailing philosophies and desired outcomes. This goal was complicated by the misconceptions of educators on each side of the Atlantic concerning the disciplines of science and geography. The partnership of educational systems required that we both accept that:

Earth System Science and the study of the environment is a human enterprise that includes the ongoing process of seeking explanations and understandings of the natural world. One of science's principal characteristics is its dynamic nature. If this discipline of education is to achieve its potential in helping students achieve this goal, then learning experiences must strengthen the science foundations of the student by emphasizing and employing the scientific methods, concepts, and knowledge that have brought society to its current levels of development. (Arnold, 1991). If teachers are to be able to "lead" students toward this goal, they will have to engage in activities that will not only enrich their own education, but also that of their students. There is a strong feeling among the scientific community that disciplines should be merged and treated as interrelated parts of a single discipline... that students should become aware of the "themes of science" and helped to develop "scientific ways" of looking at their world (LaPointe,1991).

Perhaps nothing enlightens students more than being able to engage in the process of learning. Students who participate in field experiences become involved in the skills of observation, data collection and analysis, and the utilization of the tools of the professional community. Students who have engaged in field studies are often awed by the learning atmosphere (Arnold, 1993). Through field experiences, students would come to realize that knowledge in science is tentative and human-made, that doing science involves trial and error as well as systematic approaches to problems. More importantly, field experiences result in the knowledge that science is something they can do themselves (LaPointe, 1991). Real-life problems are an effective method of raising students interest level. Students are forced to use their new-found knowledge to help retain the lessons they have learned long after their studies are over. Thus putting science information in context with real-world problems helps both teachers and students learn the importance of the specific concepts being taught (Glantz,1993).

As the leader of past mountain expeditions, it was clear that hourly manual measurements of weather had a great benefit in providing useful introduction in the use of instruments but the quality and amount of data proved of limited value. Of primary concern was that data could only be collected while students were present at the research site. There were startling weather effects in the valleys which needed to be explored and not least of these was the katabatic winds. Studies of vegetation had already shown the differences between proximal and distal slopes which could only be explained with more detailed meteorological data.

As a result of the chance meeting at the previously mentioned conference, an invitation to participate in the 94 Expedition opened new avenues of partnerships by persuading an American science teacher to volunteer expertise associated with his involvement with the AERA division of the AMS. His suggestion to involve American students "to carry equipment" was readily accepted. Remarkably, our ideas concerning the learning objectives for student fieldwork were similar. Students were expected to be much more that Sherpas. Activities were designed to make it possible for them to ask the questions, to devise strategies, and to solve problems and verify their results. They were then engaged in the process of solving the puzzles that raw data always seems to initiate and thanks to this conference, work towards a deadline in making results presentable.

Feedback from the expedition leader indicated that two proposed studies would not only enhance the program, but also provide much needed data for student research. The two studies that were identified involved the determination of the energy budget for the glacial valley and the dynamics of the katabatic glacial winds. The identification of these research problems was prompted by past involvement of the UnitedStates author as an intern with NOAA during the summer of 1991 and consulting provided by the meteorology department ofthe Pennsylvania State University.

Prior to the American involvement with this endeavor, only limited experience with partnerships had been experienced. However, The expedition leader, George Meldrum, had considerable experience in this regard (Meldrum, 1993) and through his encouragement and assistance, efforts were made to involve American industry, federal agencies, professional societies, and university partnerships toward what was becoming an International Expedition.

The energy budget experiment was the most complicated of the experiments. The Atmospheric Turbulence and Diffusion Division associated with NOAA, and Dr. Dennis Thomson of the Meteorology Department of Penn State University were instrumental in designing and supporting the research. Each institution provided sophisticated instrumentation and expertise toward the design. As the design developed, it became apparent that student involvement from the United States would be beneficial. Penn State offered to train students in the operation of the equipment and the critical aspects of the experimental design. Through their assistance, a team of five students was provided instruction in micro-meteorology, instrumentation, and involved in the construction of some of the instrumentation. The State College Area School District provided instructional support concerning the science that would be required for the expedition, and e-mail contacts with scientists at ATDD of NOAA and glaciologist at Penn State and the University of Washington. As the equipment needs were being assessed, it was determined that computer technology not available to the authors would be required. Portable lap top computers would be needed to access the data from the Campbell data loggers provided by Penn State and ATDD. The Center of Academic Computing at Penn State provided a modified 386 IBM to meet our requirements. The Eduquest program sponsored by IBM Corporation supplied a 486 Think Pad 350 for student use. Additional data loggers and meteorological equipment were made available from the MJP Company in Cornwall, UK, and the Royal Meteorological Society. Dr. Charles Duncan, Meteorology Department, Edinburgh University has given advice to the expedition members through his role as "Adopted Meteorologist" to James Gillespie's High School. The Adopted Meteorologist Scheme is organised by the Royal Meteorological Society. Parents in Scotland constructed the needed towers and protective shields and boxes for the experiment.

As discussed earlier, previous expeditions to glacial research stations, indicated a need for more specific meteorological data that would support investigations in the disciplines of biology and geography. In this expedition, data collection was expanded to cover a 24 hour period and not limited to the time period that the student teams were at the site. In addition, this year a comprehensive effort would be made to determine the characteristics of the katabatic flow of air referred to as the "glacial wind". Faculty from the Penn State Meteorology Department were instrumental in helping design the experiment. Neutrally buoyant balloons would be employed to determine the dynamics of the streme flow. However, in order to properly deploy the balloons, the experiment required knowledge about the time of the maximum winds. Through the cooperation of the Davis Instrument Company of Hayward, California, the expedition was loaned a portable meteorology station that was capable of recording data for twenty four hours and storing in a data logger at five minute intervals. Data was then downloaded daily to a Powerbook lap top provided by the State College School District. The Davis Instrument package proved to be very valuable for the wind experiment as the data provided was instrumental in developing a model for the katabatic flow.

Without the partnerships that have been identified, the inclusion of the meteorology experiments could not have occurred. That is not to say that all activities went without incident. One of the benefits of engaging students in field research is to initiate them into the realm of research and to allow them to become involved in the same problem solving exercises that confront professionals in the field. Through practical experience students learned how moisture (rain) can cause havoc with electronic instruments, the difficulties of maintaining electrical currents required of sophisticated instruments via battery failure, and the need to repair and troubleshoot complicated problems under adverse conditions. In addition, they learned the value of advanced preparation and the difficulty of problem solving when details are not attended to. As an example, it is difficult to render corrections when the operators manual is left at the camp site 15 kilometers distance which requires one to traverse 3 kilometers up and down a mountain. Simple mistakes early in the studies resulted in lost data, but reinforced excellence in techniques as the study progressed. Students soon realized that their success in obtaining data was a function of their skills and quickly adapted. Problem solving skills became well honed, team cooperation became evident, and success was welcomed with smiles and "high fives".

One of the most important lessons that can be imparted to young people engaged in their first real research activity is the need to complete the cycle. That is, the research is not over when the fun of collecting data is completed. Research to be of value must be analyzed, evaluated, and reported. Instruments must be recalibrated and tested. We were fortunate that the AMS permitted us that forum this year. Selected students involved in data analysis were invited to present posters at this conference. Thus, the real panic began shortly after their return. It is never too early to introduce them to the "publish or perish" syndrome. Teams from both sides of the ocean worked feverishly trying to comprehend the data and express their findings in a meaningful manner within the parameters of research guidelines. They completed this task as "true partners". Many other individuals from the expedition are using the information to present work which will be assessed as part of their further studies in school.

Both authors would like to acknowledge the contributions of the universities in their respective countries. In Scotland, we were fortunate to have the active partnership of several Scottish Universities and other learned bodies who seemed to have the ability to move heaven and earth to find answers to student questions and who showed a real interest in the work being undertaken and indeed in the students themselves. A prime example of this cooperation was the impression created in the mind of the Scottish student who on returning from a visit to the geography department at Edinburgh University in search of solutions that eluded both her and teacher declared, "The Professor justtook all of the papers and spread them on the floor. He spent an hour on his hands and knees explaininghis ideas and we think we have the answer". We have received some comforting words of encouragement forthe work we have been undertaking with students, but it is satisfying when we learn that "this type of field work brings the public schools and universities closer together".

As a result of this first venture into distance field work, and international partnerships, several reflections are warranted by the authors.

1. Having organized expeditions to several mountain areas in Europe including three to Norway, it was observed that the more that was asked of the students in terms of detailed and rigorous fieldwork, the more they not only enjoyed the experience, but could deal with progressively more complex remits.

2. The approach to the study of glacial valleys with senior students was designed to present the area as a total environment and to lead them into appreciation of interrelationships with this fragile ecosystem. Past expeditions and student studies indicated that the future ventures should include more emphasis on the meteorological realm.

3. Although some time was spent teaching the students about the expectations of the experiment prior to departure, more time must be spent on each side of the ocean preparing students about the theory and ideas associated with concepts such as the energy budget.

4. A student team involved with new equipment must be given more time to comprehend the operation of the electronics and the theory behind of equipment design in order to effectively troubleshoot problems. This would imply more hands on work with the equipment prior for departure to the field site. Implicit here is that participants working with new equipment will have to be able to demonstrate and explain the materials to other members of the field study at a "home site" prior to departure to the research site.

5. The success of this operation rested on the fact that duplicate instruments were available. Whenever working in new and remote locations, back-up instruments, computers, and electrical adapting units are required.

6. With proper planning, instruction, and patience, honors students can design and implement research activities often deemed only appropriate for college students.

7. Adequate time to prepare papers is essential. There are numerous difficulties trying to coordinate communications

between international students. Fortunately both schools involved had access to e-mail and internet through the efforts of The University of Edinburgh in Scotland and The Pennsylvania State University in the United States. This particular partnership facilitated the communication between the two schools enabling us to be here today.

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J1.3 PROJECT ATMOSPHERE: AMS PRECOLLEGE EDUCATIONAL INITIATIVE - AN OVERVIEW OF PROGRESS

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1. INTRODUCTION

Project ATMOSPHERE is now in its fourth year of existence. In this brief lifespan much progress has been made to enhance precollege science education. Particularly noteworthy this past year has been the evolution of existing programs such as the Atmospheric Education Resource Agent (AERA) program and materials development. Further, several new programs have been initiated which expand upon the original vision of the AMS educational program. The following is a brief description of these existing and new programs and a status report on progress to date.

2. ATMOSPHERIC EDUCATION RESOURCE AGENT NETWORK

As has been the case since the inception of Project ATMOSPHERE, the primary component of the program is the Atmospheric Education Resource Agent (AERA) network. This nationwide cadre, which now numbers 78 master science from 46 states and the District of Columbia, has nearly reached its full complement. Future additions to the program will likely be to provide representation to those states lacking an AERA, or to replace vacated positions.

AERAs continue to conduct in-service training sessions for other teachers either locally or at regional or national teacher conventions. In the 1993-94 academic year, AERA reached over 13,000 teachers through 500 sessions. Over the past three years, AERAs have conducted over 1000 training sessions reaching over 32,000 teachers throughout the nation. Another positive benefit is that many AERAs are becoming agents of change in their respective educational systems, being appointed to committees to develop standards or modify curriculum, being elected to boards of state or national educational or professional organizations, and advocating for increased atmospheric science content in school curriculum.

Annual training for AERAs continued as in previous years. This past summer 64 AERAs attended a one-week workshop in Washington D.C., where they toured the National Weather Service headquarters and the National Meteorological Center. This was followed by a one-week program in Boulder, CO for the 27 AERAs who had not attended a similar workshop in 1992 (Smith *et al.*, 1993). In addition, 24 K-12 teachers participated in the AMS-NOAA Summer Workshop for Precollege Teachers held at the National Weather Service Training Center (NWSTC) in Kansas City, MO (for details refer to Smith et *al.*, 1991). During this program an Australian teacher and a Canadian teacher attended with support from their countries' respective weather services and professional atmospheric/ oceanographic societies.

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3. INSTRUCTIONAL RESOURCE DEVELOPMENT

Another key component of the AMS educational initiative is the development of educational materials that are scientifically accurate and pedagogically appropriate for precollege teachers. Three new teacher guides were developed for distribution as training modules for AERA workshops, similar to those in the two previous years (Weinbeck, 1993). The titles of the guides for this past year are: "Weather Radar: Detecting Precipitation", "Weather Radar: Detecting Motion", and "Sunlight and Seasons". In addition, two issues of *Look Up!*, the Project ATMOSPHERE "newsletter" that incorporates a copy of *Weatherwise* magazine, were distributed to teachers across the nation - the second issue funded with contributions from AMS 75th Anniversary Campaign. In addition, two educational resource projects are under development: an activity module on sunlight and a teacher version of a *Glossary of Common Meteorological Terms*. These materials will be marketed nationally later this year.

4. DATASTREME PILOT STUDY

Last year, Project ATMOSPHERE conducted a feasibility study to deliver near real-time weather products to a schools at no recurring cost. The DataStreme program, a joint effort of AMS, The Weather Channel (TWC) and WSI Corporation, utilize the Vertical Blanking Interval of TWC's cable television signal to transmit weather information to classrooms. Sixty-three teachers (which included AERAs paired with partner teachers in their states) from second grade through high school incorporated the data transmission in creative ways across the curriculum - from science to social studies. Responses from participant teachers were overwhelmingly positive, prompting extension of the program for a second year. Plans are underway to expand this concept to include other environmental data streams to enhance classroom instruction nationwide.

5. NEW EDUCATIONAL INITIATIVES

The AMS education program initiated two new programs this past year. The Maury Project, a K-12 teacher enhancement program on the physical foundations in oceanography, conducted its first summer workshop at the United States Naval Academy (for details refer to Smith *et al.*, 1995). A second program, held concurrently with the AMS-NOAA Summer Program for Precollege Teachers at the NWSTC in Kansas City, was conducted for educators who teach courses with weather content at community college or four-year undergraduate institutions (for details, see Weinbeck and Geer, 1995). One interesting aspect of this program was that it enabled the precollege and undergraduate educators in attendance to exchange ideas on teaching at their respective levels. Such interactions provide valuable opportunities for forming partnerships and for teachers at one level to acquire greater appreciation for the situations of their counterparts at other educational levels.

6. CONCLUSION

Project ATMOSPHERE has reached a new level of activity. The principal focus of the AMS educational initiatives continues to be precollege teacher enhancement and educational materials development on atmospheric topics. The AERA program, the centerpiece of Project ATMOSPHERE, has achieved full maturity, and continues to be a most valuable instrument for delivering atmospheric science instruction to teachers across the country. In addition, AERAs are becoming agents of change as they advocate for improving science education in their respective states. Through the DataStreme Pilot Study, Project

ATMOSPHERE is exploring new avenues for delivering and utilizing weather information to the classroom. Further, the AMS educational program is now exploring new avenues in its endeavor to enhance science education. The Maury Project and the new program for undergraduate educators represent natural extensions of the original AMS educational initiatives. These programs demonstrate the Society's strong commitment to promote educational activity at all levels.

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J1.4

THE MAURY PROJECT: A TEACHER ENHANCEMENT PROGRAM IN PHYSICAL OCEANOGRAPHY

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1. BACKGROUND

The American Meteorological Society formalized its precollege educational initiatives in 1990. This initial investment of funds and other institutional resources was intended primarily to support K-12 teachers of science with the instruction of atmospheric topics (Houghton, 1990). In 1991, the Society's commitment to the enhancement of precollege science education received a major boost with a five-year grant from the National Science Foundation, which enabled the AMS to establish Project ATMOSPHERE. The primary component of Project ATMOSPHERE was the implementation of a nationwide network of master teachers to serve as resource agents for the Society. Designated as Atmospheric Education Resource Agents, these teachers conduct hundreds of peer-training sessions for thousands of teachers in their respective states to improve the background of teachers on weather and climate (Smith, 1993). In addition, Project ATMOSPHERE has produced a variety of instructional materials that are scientifically accurate and appropriate for classroom use (Weinbeck, 1993).

In 1994 the AMS launched a new educational endeavor, called the Maury Project. This teacher enhancement program focuses on another area of AMS interest - physical oceanography. The following is a description of the Maury Project and how it is designed to promote precollege instruction of the physical foundations of oceanography.

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2. AN EDUCATIONAL PARTNERSHIP

The Maury Project represents a unique partnership of organizations with a strong interest in physical oceanography. The American Meteorological Society has an expressed commitment to the oceanic sciences, especially physical oceanography, as stated in its constitution. The AMS has joined forces with the U.S. Naval Academy, which has one of the premier undergraduate programs in physical oceanography (Smith and Gunderson, 1994). A third member of this partnership is the National Oceanic and Atmospheric Administration, which has an operational and research mission in the oceanic sciences. Another member of the partnership is the State University of New York at Brockport, which has a long standing history with precollege and teacher enhancement projects (Weinbeck and Geer, 1989). This collection of a professional society, universities, and government agencies provides a diverse group of individuals, resources, and strengths linked by the common thread of enhancing instruction for teachers on the physical foundations of oceanography.

3. DESCRIPTION OF THE WORKSHOP

The central component of the Maury Project is a series of two-week workshops (each summer beginning in 1994) conducted at the U.S. Naval Academy to train precollege teachers in selected physical oceanography topics. Over the grant period, 72 teachers, selected from elementary, middle and high school levels across the country to maximize diversity, will participate in one or more of these summer workshops. Further,

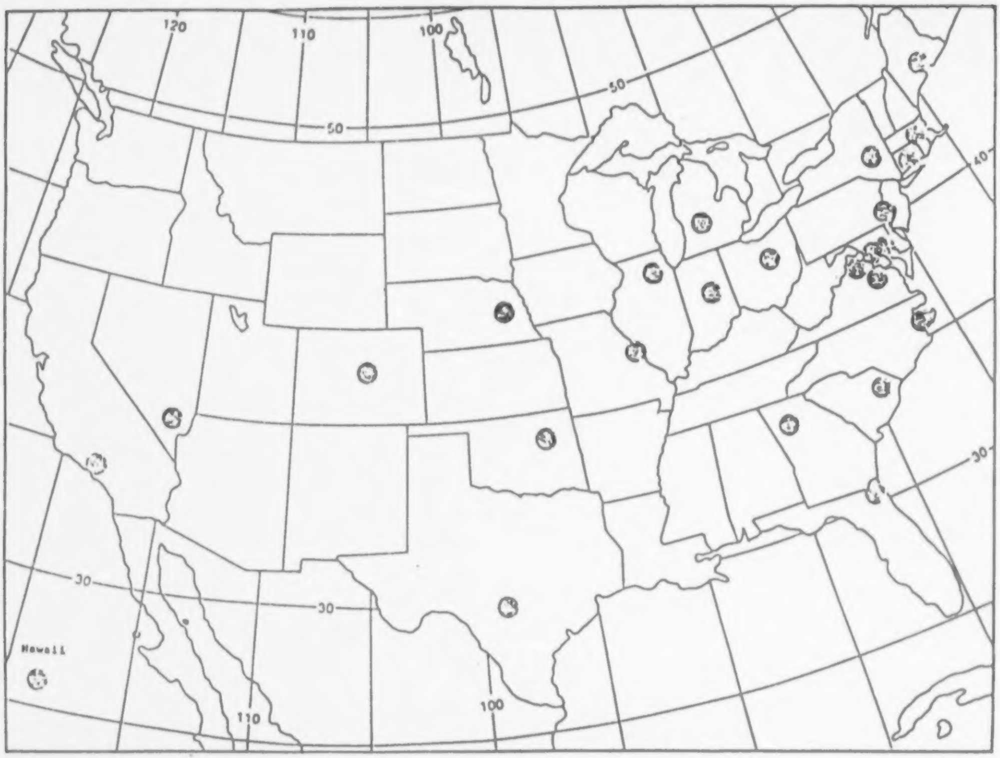

Fig. 1. Map displaying locations of teachers participating in Maury Project 1994 Summer Workshop for Teachers.

these teachers will become members of a national network of resource teachers similar to the Atmospheric Education Resource Agents (AERAs) of Project ATMOSPHERE. Fig. 1 displays the distribution of teachers (by home states) participating in the 1994 Maury Project Summer Workshop.

The instructional design of the summer workshops includes lectures with a strong hands-on laboratory component to reinforce the learning process. This component of the program utilizes both civilian and military instructional staff of the Naval Academy's Oceanography Department as well as guest speakers from a variety of oceanographic agencies within the Washington DC area. This reinforces the partnership aspect of the Maury Project and exposes participants to the diversity of the oceanographic community. Topics covered in the 1994 summer workshop include oceanographic instruments, data analysis, ocean and coastal circulations, hydrography, acoustics, satellite oceanography and polar oceanography. Hands-on exercises were incorporated to enhance the learning process as well as to provide the participant teachers with activities to take back to their science classrooms. Each of the participants were assigned to one of the project scientists to prepare an activity for their respective grade level. They demonstrated this activity to the entire group during the workshop. In addition, there were two field experiences which included oceanographic studies on the Chesapeake Bay utilizing one of the yard patrol craft at the Naval Academy as well as a coastal study along the Cheaspeake Bay.

Guest speakers from the oceanographic community in the Washington DC area were invited to give presentations on topics of their particular expertise. The Summer 1994 speakers included: Marshall P. Waters, III and Jennifer Clark (NOAA, National Ocean Products Center) - "Satellite Applications for Oceanography"; Thomas H. Kinder (Office of Naval Research) -"Research Advances in Oceanography"; Richard W. Spinrad (Office of Naval Research) -

"Ocean Modelling and Forecasting"; and CDR Terry Tielking (Office of the Oceanographer of the Navy) - "The Future of Oceanography". In addition, the participants visited the Department of Commerce, where they were addressed by D. James Baker (Undersecretary of Commerce and Administrator of the National Oceanic and Atmospheric Administration [NOAA]), Kathryn D. Sullivan (Chief Scientist, NOAA) and David Goodrich (NOAA Office of Global Programs). The teachers also toured the NOAA National Ocean Products Center and the Naval Ice Center to get first-hand exposure to operational oceanography.

A final component of the workshop included pedagogical instruction and exposure to precollege educational programs in the oceanic and related sciences. In the Summer 1994 Workshop, James R. McGinnis (University of Maryland at College Park) provided his insights on ways to enhance science education and how to best incorporate the experiences of the Maury Project workshop into the science classroom. James V. O'Connor (University of the District of Columbia and former president of the Marine Educators Association) discussed precollege educational programs in the ocean sciences. Ira W. Geer (Education Director, American Meteorological Society [AMS]) and David R. Smith (Oceanography Department, United States Naval Academy and Chair of the AMS Board on School and Popular Meteorological and Oceanographic Education) provided background on AMS K-12 education programs.

These activities provided the participant teachers with valuable background information on physical oceanography from operational and research perspectives. In addition, the teachers were exposed to the major agencies involved in oceanic sciences as well as how these organizations are promoting education at the precollege level.

4. MATERIALS DEVELOPMENT

Another important component of the Maury Project is the development of instructional materials. The intent is to provide activity-based materials for teachers to enhance their knowledge of physical oceanography. In the first year, two teachers' guides were developed, entitled Wind-driven Ocean Circulation and Density-driven Ocean Circulation. These modules include basic understandings, or brief statements that capture the fundamental essence of the respective topics, as well as a short narrative that describes the phenomena in more detail. Finally, there is an activity that provides hands-on experience to enhance learning.

The teachers' guides are the basis for the participant teachers to conduct peer training sessions for other teachers. Such sessions are conducted as in-service training in their respective schools or school districts or at state, regional or national science teachers conferences.

5. EXPECTATIONS FOR THE FUTURE

The Maury Project is designed to enhance precollege education on the physical foundations of oceanography. Summer workshops for teachers represent the first step in the process, in which 72 teachers from across the nation will attend one or more workshops at the Naval Academy. Many of these teachers may then be selected as resource agents to conduct peer-training sessions for other teachers. These sessions are single-topic workshops conducted for other teachers as in-service training in their respective schools or school districts, or at state, regional or national science teacher conferences. The workshops are based on the teachers' guides developed specifically for the Maury Project. Each participant teacher is expected to conduct no less than two such workshops per year, although Project ATMOSPHERE experience suggests that the participant teachers will conduct more sessions for their peers than just the required minimum. This grassroots approach has a multiplicative effect on teacher enhancement, reaching far greater numbers than could be reached by the limited staff of the Maury Project. In addition, it promotes a sense of professionalism among the teachers themselves, who grow in self-esteem by presenting the material to their colleagues. It also is a much more sound pedagogical model because the teachers are better prepared to adapt the materials to fit the needs of their colleagues in their respective school situations.

Future materials development include two additional teachers' guides each year and other materials deemed necessary to enhance the teaching of the physical foundations of oceanography at the precollege level. Often, suggestions for materials come from the participant teachers themselves, representing those instructional materials that they believe would best benefit the classroom teacher. For example, Project ATMOSPHERE has developed videotapes and transparency sets to enhance classroom instruction. Similar developments are likely for the Maury Project.

Finally, and most importantly, is the long-lasting benefit of the partnership that will evolve as a result of this endeavor. The network of master teachers as resource agents in conjunction with the organizations supporting the Maury Project will generate a relationship that far exceeds the sum of its parts in terms of its ability to enhance precollege instruction of physical oceanography. Such partnerships enable individual groups to blend their respective strengths with others, resulting in a composite force far more capable of addressing issues to enhance the educational process, than working alone or apart. The Project ATMOSPHERE model has demonstrated the power of such partnerships of professional scientific societies, universities, and government research and operational agencies working in concert with precollege educators to improve science instruction. Undoubtedly, the Maury Project will experience the same level of success to enhance the understanding of the physical foundations of oceanography.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the United States Naval Academy for its support of the 1994 Maury Project Summer Workshop. In addition, the support of several outside agencies was also most beneficial, including the National Oceanic and Atmospheric Administration, the National Ocean Products Center, the Office of the Oceanographer of the Navy, and the Office of Naval Research. Further, consultation from Dr. James R. McGinnis (University of Maryland) and Dr. James V. O'Connor (University of the District of Columbia) provided invaluable insight for the summer workshop.

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J1.5

THE WEATHERWATCH LEADERSHIP NETWORK

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1. INTRODUCTION

The WeatherWatch Leadership Network (Project WeatherWatch) is a three-year project, sponsored by the Teacher Preparation and Enhancement Program of the National Science Foundation, designed to increase and improve the use of science inquiry in the teaching and learning of weather in elementary and middle schools in New York City.

As a result of their involvement in the project, teachers will develop the capability of using a computer-network linkage between The City College of New York (CCNY) and participating schools. This electronic connection will allow for the transmission of current-weather products directly into their classrooms.

2. OBJECTIVES

The objectives of Project WeatherWatch include the following:

(1) Improving the teaching of weather through using curricula, materials and strategies that develop teachers' knowledge and understandings of meteorological content and enable teachers to become effective practitioners of inquiry methodology;

(2) Developing teachers' ability to use computers and modems in classroom networking activities in order to allow for the acquisition of real-time weather information, the exchange of school-based meteorological observations, curriculum development and interactive telecommunications projects;

(3) Preparing exceptional teacher participants for curriculum leadership roles in their school districts.

3. CRITERIA FOR WEATHERWATCH PARTICIPANTS

The criteria for selection of participants to WeatherWatch include:

1. Certification in science (middle school teachers).
2. Expressed interest in weather, inquiry teaching, technology, and leadership.
3. Recommendation of the district science coordinator and school principal.

An additional pledge was required from district and school administrators. Each participant accepted by the project has received a written commitment of support for the purchase of the computer hardware and the establishment of telephone connections to modems which are essential for the telecommunications activities of WeatherWatch. The minimum hardware requirements include a 486DX2 66 megahertz PC equipped with 8 megabytes RAM, a 400 megabyte hard disk and a 14.4 bps modem.

4. TELECOMMUNICATIONS LINKS

A new electronic link will shortly be established between CCNY and the schools of participating teachers. This connection will provide educators with a variety of weather products including satellite-cloud imagery, radar graphics, surface observations, and text bulletins. It is anticipated that much of this weather information will be provided by the University of Michigan's Weather Underground services, "Blue-Skies" and "UM-WEATHER." An agreement is now in place that will allow for CCNY to become a "mirror site" for Blue-Skies. In effect, this arrangement will enable all WeatherWatch participants to access The Weather Underground data base through a local call to the college. The current system overview is illustrated in figure 1.

Additional weather information products will be obtainable through Gopher links (very likely using a Mosaic interface) to Unidata, to the University of Illinois' Daily Planet, and to other sites, when necessary.

5. CLASSROOM ACTIVITIES

The classroom educational program planned for WeatherWatch includes the exploration of weather by means of on-site school observations and the analysis and interpretation of weather information transmitted to schools by the college network. Grade-appropriate curricula and activities are currently being developed by project personnel for pilot testing in schools.

Students will also be engaged in the exchange of school observations through e-mail messages sent daily to all pupils participating in the project. Personal remarks and anecdotes about the weather will accompany these readings in order to encourage a "community commentary." It is anticipated that school

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observations will also be shared with pupils in other cities throughout the nation via e-mail.

Students will not be the sole beneficiaries of the electronic network. Teacher participants of WeatherWatch will be sharing their ideas as well as any problems, either technical or educational, among themselves and with the project staff through e-mail communications. Additional curriculum information, particularly materials developed by the AMS Education Program, will be available to teachers from Blue-Skies.

6. SUMMER AND ACADEMIC YEAR ACTIVITIES FOR PARTICIPATING TEACHERS

During the three years of the project, three groups of teachers will receive extensive training and support which will provide them with the skills and technical assistance needed to successfully conduct weather-education programs in their classrooms.

WeatherWatch is employing a multi-pronged approach to engage teachers in the work of the project including: a month-long Summer Institute integrating atmospheric science content, an introduction to electronic networking and classroom weather-study applications; an academic year course that includes telecommunications, additional content study in meteorology and leadership training; monthly curriculum development and project discussion sessions; on-site support for electronic networking.

7. THE SUMMER INSTITUTE OF 1994

The initial Summer Institute for WeatherWatch began on June 30, 1994 and concluded on July 28th. Twenty four teachers were in attendance for 19 days.

A typical daily schedule included the following activities:

(1) A three-hour morning session, each day, focusing on a single topic. Among the themes presented were: Sensing and Analyzing Weather; Water Vapor/ The Water Cycle/ Clouds; Weather Systems; The Upper Air; Weather Forecasting; Weather Satellites; Weather Radar; Hazardous Weather: Hurricanes; Thunderstorms and Tornadoes; Climate/ Global Climate Change.

(2) Each afternoon session began with a thirty to forty-five minute hands-on activity related to the morning's topic.

(3) The afternoon sessions concluded with a seventy-five to ninety minute period of curriculum and/or weather-education activity writing, again, based on the topic of the day.

The instructional team for the atmospheric-science content presentations consisted of WeatherWatch Project Coordinator S. J. Richards, Prof. S. D. Gedzelman and Prof. E. Hindman, the latter, members of the CCNY Earth and Atmospheric Sciences Department.

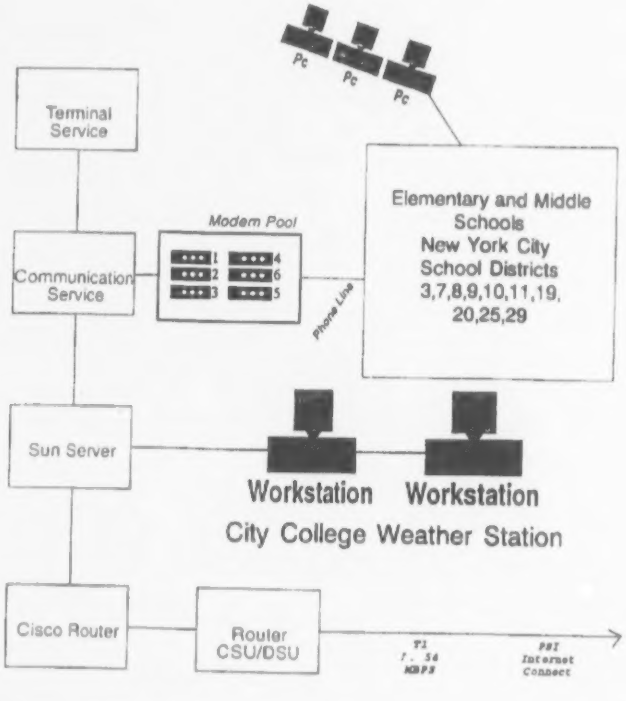
Pc
Pc
Pc
Terminal Service
Modem Pool
1
2
3
4
6
5
Communication Service
Phone Line
Elementary and Middle Schools
New York City School Districts
3,7,8,9,10,11,19,
20,25,29
Sun Server
Workstation
Workstation
City College Weather Station
Cisco Router
Router CSU/DSU
T1
1.54
MBPS
PSI
Internet
Connect

Figure 1. Current System Overview.

Two guest speakers were invited to make presentations. Dr. David H. Rind, a climate research specialist at the Goddard Institute for Space Studies in New York City, spoke on the topic "Global Climate Change." Also, Dr. Nicholas Coch of Queens College, an expert on the effects of hurricanes on the coastal environment, addressed WeatherWatch teachers.

Three full days of the Summer Institute were allotted to an "Introduction to Telecommunications." Prof. Sheila Gersh, CCNY School of Education telecommunications specialist, led participants in an initial exploration of Telnet and Gopher weather-information servers on the Internet. For most teachers, this was their first experience in accessing information from the Internet. Their response was overwhelmingly positive.

8. PLANS FOR THE IMMEDIATE FUTURE

WeatherWatch looks forward to the following milestones during the Fall, 1994:

(1) The placement of computer hardware in participating schools.

(2) The establishment of a computer linkage between CCNY and classrooms of participating teachers allowing for the telecommunication of weather information to schools.

(3) A follow-up course to the Summer Institute that will focus on telecommunications, additional content study in meteorology and leadership training.

(4) The establishment of a "mirror site" for Blue-Skies at CCNY.

9. ACKNOWLEDGMENTS

Funding for Project WeatherWatch was provided by the National Science Foundation through grant number TPE-9353451. The author is also very grateful for the considerable encouragement, advice and assistance provided by Dr. Ben Domenico of the Unidata Program Center during the planning stages of the project.

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J1.8 HOW DID YOU BECOME INTERESTED IN ENVIRONMENTAL SCIENCE?

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1. INTRODUCTION

The Atmospheric Environment Service (AES) is an organization based upon science in which approximately 15 per cent of the professional and technical staff are females, occupying a variety of scientific positions. The careers of these women provide an excellent example of the opportunities that are available to young girls in the scientific fields. This presentation discusses how a cross section of these women became interested in the environmental sciences, the positions they occupy and their scholastic backgrounds.

2. THE SURVEY

To obtain the information required for this presentation a survey was circulated to the pertinent female staff. Of the 131 questionnaires sent 89 (68%) were returned. The survey was separated into 5 sections. Section 1 covered personal information, section 2 dealt with occupational information, and scholastic information was covered in section 3. Section 4 asked the question, "How did you become interested in environmental sciences?". The last section asked the question, "What would you have to say to a young girl who is considering scientific studies?".

3. THE RESULTS

3.1 *Demographics*

Women have occupied scientific positions within AES for the last 30 years, but their numbers were much smaller in the early years. Figure 1 represents the distribution of the percentage of respondents versus their years in the service. About 15 years ago a significant increase occurred in the number of respondents that joined the service. This was probably a sign of the times as the women's groups were becoming more vocal and it was becoming more acceptable for girls to study in non traditional fields.

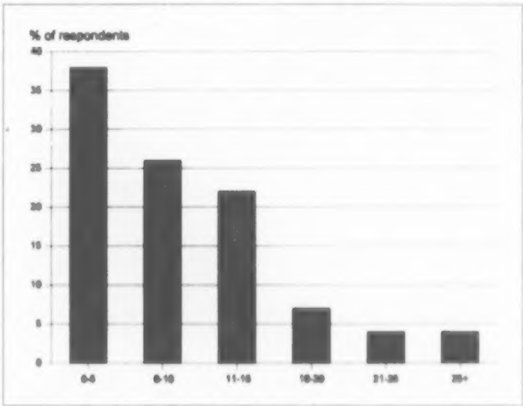

Figure 1. Years of Service.

3.2 *Position description*

Women within the AES occupy many scientific positions. Figure 2 represents the percentage of respondents versus each occupation. The large number of meteorologist is not surprising since the AES is primarily involved with atmospheric phenomena and weather forecasting. What the figure does not show is that within each field women occupy positions at every level.

In the case of meteorologist we have a regional director general, a director of development, scientific service meteorologists, many supervisors and senior meteorologists and instructors, as well as meteorologists at the operational level.

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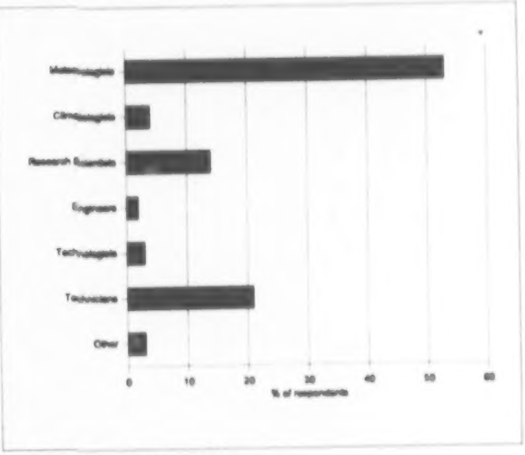

Figure 2. Occupations.

3.3 *Education*

Figure 3 shows the breakdown of the highest level of education achieved by each respondent. The major areas of study seems to be physics, mathematics, meteorology, chemistry and atmospheric sciences. Sixty three percent of respondents also indicated that they have taken additional studies while on the job. Some of the courses taken were meteorology, computers, education, atmospheric chemistry and oceanography.

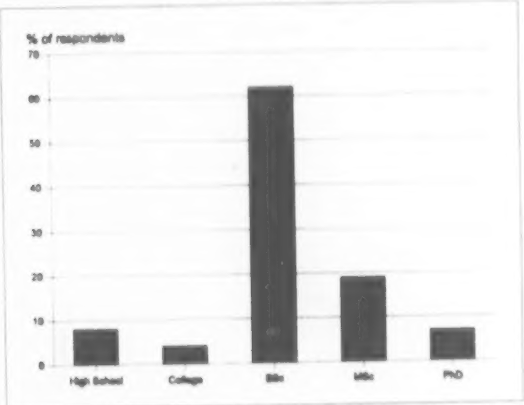

Figure 3. Highest Level of Education Achieved.

4. THE ANSWER TO THE QUESTION

The specific answers to the question, "How did you get interested in environmental science?" were varied (that is to be expected) but many of them have a recurring theme. Most of the respondents indicated that they have always been interested in science in one way or another and, as a result, science was not usually a problem at school. Many indicated that their families had a great effect upon their choice of a career in science, either by their support or by having a family member involved in the field. School was also a great influence on the respondents; many indicated that their interest in their future careers bloomed during a certain class. Teachers were also big motivators. Their enthusiasm and support made some subjects so interesting they just had to be pursued. University recruitment and summer jobs also resulted in career path decisions, but to a lesser degree.

5. CONCLUSION

In conclusion I leave you with the answers to the last question, "What would you have to say to a young girl who is considering scientific studies?". The overall answer was a resounding "Go for it!". Most of the respondents indicated that their science related positions are challenging and rewarding and that the opportunities open to them are great. Many had also mentioned that they have had no great problems combining a career with a family. A few added recommendations were made. The first one was that science is a great base for whatever the student wants to do in the future and that even if she does not plan to pursue a career in a scientific field, she should try to take science and mathematics, at least through high school. It was mentioned that to drop these subjects in high school could result in closed doors in the future. The second suggestion was that if a student is thinking of a career in science she should look into the subject a bit more i.e. take more classes in the subject, talk to people in the field, and try to get a summer job in a related field to see if she really likes it. The last parting piece of advice is that a career in science may not always be easy but it is worth it.

J1.11 4-WINDS, A TELEVISION EDUCATION PARTNERSHIP

Robert T. Ryan *

WRC-TV

Washington, DC

1. INTRODUCTION

Within the last few years a number of companies have developed meteorological systems which interface with computers and telephone lines to allow remote access of weather data. As these systems developed, it became obvious that such systems also lended themselves to education by allowing students to access data from other sites and also look at time based weather data on a classroom computer. For a number of years broadcasters have talked about putting weather instruments in schools as a way of "reaching out" to the local community and now with these "interactive" systems, broadcasters throughout the country are establishing mesonetworks of school based meteorological systems.

2. THE 4-WINDS IDEA

4-WINDS stands for Channel **4-We**ather **IN**teractive **D**emonstration **S**choolnet. In the summer of 1993 we (WRC-TV) began discussing the idea of placing weather instruments in local schools, especially "at need" schools. Preliminary discussions were held with a vendor of mesonet systems and a preliminary budget developed to establish an initial network of about 20 sites. To assist in developing the program we formed an advisory group consisting of the education chair from the local AMS chapter, 2 local AERAs (Project Atmosphere), representatives from the National Geographic Society, and educators involved in similar "outreach" efforts. The group reached the conclusion that for any "outreach" effort to be successful, the point of contact should be the local teacher, not the school principal or school system administrator, although their support was critical. The advisory group drew up the basic outline of the program, which included area meteorologists assisting as volunteer technical support personnel, the selection criteria, and workshops with stipends for the teachers supported by the program.

2.1 *Corporate Partners*

When the basic outline of the 4-WINDS program had been drawn up, a proposal was written and submitted to local corporations that had expressed an interest in supporting the 4-WINDS idea. Giant Inc. (a Washington based supermarket chain) and Hughes Information Technology Inc. provided the funding for 40 complete systems and funding for stipends for the 40 teachers who were to be supported by the program.

2.2 *4-WINDS Meteorological System*

A local company (Automated Weather Source Inc. (AWS), Gaithersburg, MD) provides all the hardware and software that is the heart of the 4-WINDS program. Through the initial funding provided by the corporate partners, 40 complete systems (hardware and software) were given **free** to 40 schools and 20 software packages were given to other teachers. The AWS system consists of a sensor suite (outdoor and indoor thermometer, humidity sensor, barometric pressure tranducer, anemometer and wind vane, rain gage, and light sensor), data logger, cabling from the sensors to the data logger, interface with a classroom computer, software (either PC or Macintosh) and computer modem. Data is displayed at the classroom computer or digital display (optional) and can be accessed by other schools, or WRC-TV by telephone. AWS software also allows each individual site to be accessed, in real time, from WRC-TV and the data shown "live" during local newscasts. AWS has also developed teacher classroom material for elementary, middle and secondary schools.

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2.3 *Selection Process*

The 4-WINDS advisory committee, and the corporate partners, supported the idea that this program would be especially valuable to "at need" schools and teachers trying to bring science and math education into the "real world". WRC-TV contacted all the area school superintendents and science coordinators to let them know of the 4-WINDS project and invited them to a special "kick off" program where 4-WINDS was formally announced. The "kick off" was broadcast on all our local news programs and area teachers were invited to write in to receive more information about the program. A packet of material containing a description of the program and the idea, an overview of the AWS hardware and software, an article by R. Ryan (*A Window on Science*) and an application form was sent to all teachers who wrote requesting information. More than 800 information packets were sent to area teachers! Requests came from western Maryland to southern Pennsylvania, near Richmond and even Baltimore, a different television market. Of about 800 packets sent out, 500 applications, for the 40 complete systems, were received. The returned applications were first sorted by county and school level (elementary, middle, high). The advisory committee also served as the selection committee and broke the number out that should go to each area to give both an geographic and educational distribution. Each application was read, often with extensive supporting material and letters from the school principal and other teachers. One of the criteria, mentioned in the information packet, was the desire to place the equipment in schools where the system would be used by a number of teachers. In the end, the final cuts were very difficult and by running a very tight budget 20 deserving teachers were provided just the AWS software so they could still access the 4-WINDS weather station at a nearby school which had the complete system . The selected teachers were notified by a personal call and follow-up letter and invited to the 4-WINDS workshop.

2.4 *4-WINDS Workshop*

The first 4-WINDS workshop was held at WRC-TV in January 1994. Dr. Joe Friday and Dr. Kathleen Sullivan were feature speakers. Each teacher was assigned a "4-WINDS technical partner" who were local NOAA meteorologists, Hughes technical volunteers and in some cases technical volunteers form WRC-TV.

The installation of the AWS equipment was outlined and the experiences of local teachers who had previously purchased the equipment was covered in the workshop. Additionally each teacher received a copy of the *USA Today Weather Book*, and a variety of educational material form NOAA and WRC-TV . The workshop also included presentations on *Project Atmosphere*, using weather information to teach geography, a tour of the WRC weather office and news studio and time for the many questions. At the conclusion of the workshop the teachers were provided either PC or Mac software (depending on individual needs). The hardware was delivered to the schools within 10 days of the conclusion of the workshop.

3. 4-WINDS IN OPERATION

Some schools were able to install the AWS hardware within 1 week after delivery. A few teachers, because of changing classes and administrational difficulties had to wait months before getting "on line". The greatest difficulty has been getting a phone line into the classroom to be able to fully utilize the 4-WINDS system. Some teachers also have also expressed frustration with the educational bureaucracy in getting the installation done properly. In most cases the school principals and area science coordinators have been enthusiastic supports of the program. By June 1994, 37 of the 40 4-WINDS hardware sites were "on-line".

As part of WRC-TV weathercasts the entire network is accessed and a geographic range of schools shown on local maps. Featured schools are often shown "live". The actual readings at the "4-WINDS school of the day" can be shown by telecommunicating with the school. Students are very enthusiastic about "seeing their weather station on TV" and seeing maps displaying the weather at other schools. Software is currently being developed to allow for the network to be automatically accessed and the data automatically plotted on existing TV weather graphics systems.

The response from treachers has been very positive. They now have "real" data to use in various units on science, geography and math. Students interested in everything from environmental studies to computer networking have been contributing to the use of the 4-WINDS system in area schools. A number of area newspapers have published articles about the program and the corporate partners (Giant and Hughes) as well as WRC-TV have gotten extremely positive feedback. This has been a "win-win" educational/corporate outreach effort.

4. FUTURE PLANS

Corporate funding has been renewed for a second year. With the expected funding, another 30-40 complete AWS systems will be donated to area schools. Many of the teachers who have received only the 4-WINDS software last year will be receiving the complete AWS meteorological system. By January 1995 there will be a Washington based mesonetwork of almost 100 schools participating in the 4-WINDS program! This includes schools receiving the systems provided by corporate support and those schools purchasing the AWS system on their own.

The second 4-WINDS workshop will be held in November 1994. The workshop will include a number of presentations on new uses of weather data in the classroom, networking ideas and teacher and student feedback about the 4-WINDS program.

For further information about this program and the mesonet system, write to the author or contact Automated Weather Source Inc.

J1.12

THE COOPERATIVE EFFORTS OF EDUCATION RESOURCES ENHANCES THE PRODUCT

Ray Boylan and Pat Warthan*
WSOC-TV Towers High School
Charlotte, NC Decatur, GA

The broadcast meteorologist and the educator are generally perceived to be expert in their respective fields. When afforded the opportunity to share their expertise with students and teachers that perception is enhanced and indeed, deserved. The Master Teacher who, by dedication to students and education, supplement their training by investment of time and energy to become AERAs (Atmospheric Education Resource Agents) are invaluable tools to classrooms, schools and communities.

When these talents and energies are combined in a concerted and organized program they lead to an exciting infusion to education and the learning process.

Many broadcast meteorologists visit classrooms and allow visits from precollege classes; however, the contributions made by broadcast meteorologists to enhance the precollege meteorologic education are most useful when broadcasters work with precollege and college educators to broaden the scope of what happens in the classroom. This can be done through coordination with educators and through cooperative efforts to enhance what happens in the classroom.

A survey of the 78 Atmospheric Education Resource Agents of the American Meteorological Society found that 23 television broadcasters and 3 radio broadcasters have attempted to become more involved in the process of working with educators to present workshops for teachers, using students or classes as "guest broadcasters" and coordinating weather information and explanations with the curriculum being presented in the classrooms served by the media.

Some of these broadcasters have served as science fair awards speakers and/or judges; some have conducted whole school assemblies; some have had classes or students as "guest broadcasters"; several have worked with educators to conduct workshops on hazardous weather or copresented with educators at Project Atmosphere Workshops.

The television meteorologist has the unique opportunity to serve the science of meteorology, enhance the learning process, build the audience base, his/her own credibility and provide stimulus for advertiser clients at the station.

It is no new phenomena to find the broadcast meteorologist in the classroom and highlighting those visits on their broadcasts. By joining forces and cooperating with local and regional AERAs the impact of those visits can be broadened to include in-service seminars with educators. Teach a class and reach 60 students...Teach 60 teachers and reach thousands of students!

The technological explosion in remote sensing, recording, manipulation, transfer and sharing of data has opened a whole new and exciting area of educational and ground-truth data. Vendors are clamoring to install their systems in the market and partnerships with advertiser clients have proven to be fiscally provocative fields of new revenue.

The cultivation of managerial positions in school districts goes a long way toward providing easier access to a multitude of schools and educators. Keep in mind that a partnership should provide the funding necessary to initiate these programs.

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J6: JOINT PAPERS

"NEW TECHNOLOGIES FOR THE CLASSROOM"

FOURTH SYMPOSIUM ON EDUCATION

and

11TH CONFERENCE ON INTERACTIVE INFORMATION AND PROCESSING SYSTEMS (IIPS) FOR METEOROLOGY, OCEANOGRAPHY AND HYDROLOGY

PAGES: (J6) 1-58

J6.1

EXPLORING the Use of Weather Satellites in the K-12 Classroom

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1. FLORIDA EXPLORES!

To encourage an enhanced scientific awareness in the State of Florida, the Florida Technological Research and Development Authority (TRDA) created an initiative in 1992 to provide funds to make APT-capable weather satellite ground stations available to Florida's public schools. In an attempt to prove the feasibility of introducing meteorology, and specifically satellite imagery, as a vehicle to teach integrated science and applications, four demonstration/training sites were selected in 1992 to test curriculum and the effectiveness of popular meteorological education to meet these goals. This past summer, two and one-half years after its inception, the EXPLORES! program welcomed its 100th school to the program. Since 1992, 107 NOAA Direct Readout satellite data ground stations have been installed at elementary, middle and high schools throughout the state. In addition, annual training and curriculum development workshops have been conducted to provide the necessary training so that these systems may be used to their maximum extent. This combination of providing the ground stations, training and curriculum is unique when compared to all other efforts of its kind.

The original deployment of ground stations in Florida's schools coincided with the observance of the International Space Year, 1992 - the 500th anniversary of the voyage and explorations of Columbus. In honor of all scientific explorations past, present and future, the program was christened FLORIDA EXPLORES! (EXPloring and Learning the Operations and Resources of Environmental Satellites, Ruscher et al 1993). The current suite of ground stations are receiving Automatic Picture Transmissions (APT) from operating polar orbiting satellites. Sites which have demonstrated superior competency with the APT systems are also provided with the equipment which enables them to receive Weather Facsimile (WEFAX) data from geosynchronous (GOES) weather satellites with direct readout capabilities. Approximately one-half of our 107 schools, over 80% of those eligible for upgrades, will have WEFAX capabilities by the end of 1994.

In 1995, the program continues to expand. The State of Florida is undertaking a program to provide direct-line or modem dial-up full INTERNET access into all Florida schools. Many of the original participants in this effort are also EXPLORES! participants. In order to meet the needs of these schools in terms of classroom applications for INTERNET, EXPLORES! now provides a Home Page on the World Wide Web, accessible using Mosaic (available from NCSA at the Univ. of Illinois). This page includes satellite imagery as well as curriculum activities. We invite you to utilize this page in support of your popular meteorological education activities:

http://thunder.met.fsu.edu/explores/explores.html

2. CURRICULUM DEVELOPMENT

An intensive program to develop materials for the teachers and students is continuing. These materials and projects are being developed in conjunction with FSU's Department of Curriculum and Instruction (Science Education) to take advantage of the existing capabilities and facilities of each school selected, and to provide a wide variety of activities for the various educational and interest levels that Florida's diverse school-age population exhibits. Using the resources available, an instructional guide to weather satellites was created to provide information concerning the history of weather satellites, how satellites are placed in orbit, how they function, their capabilities and instrumentation, etc. Pictures and diagrams were used wherever possible to help teachers and students visualize the amazing capabilities of these space-borne earth observing stations. *NOAA Technical Report - NESDIS #44* by R. Joe Summers (1989) was provided to each participant to instruct the teachers and students on how the direct readout ground station components work to receive satellite signals and how these components transform the signals into visual images. Instructions on how to set up

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corresponding author address: Dr. Kevin A. Kloesel, Dept. of Meteorology, Fla. St. Univ. Box 3034, Tallahassee, FL 32306-3034; kloesel@met.fsu.edu the ground station, including installation of computer video and receiver boards and antenna construction were also provided. In addition, workshop sessions designed to expose the teachers to the basics of meteorological knowledge were conducted. Included in these sessions were trips to the Melbourne NWS office (modernized) and the Flight Forecast and Range Safety Facilities at Cape Canaveral Air Force Station. Workshop sessions on satellite imagery interpretation, and developing observational skills were also held. With this knowledge, the ground stations can be used to their maximum capabilities, providing an extraordinary learning experience for both the teachers and students. Units for the meteorological curriculum included basics such as temperature, humidity, winds, thunderstorms, hurricanes and tornadoes, safety precautions and procedures, regional and local climate, and the hydrologic cycle and its importance, as well as more complicated issues such as radiative transfer, the dispersion of pollution and global climate change.

Specifications for constructing school-made weather stations are also being made available to interested industrial arts and vocational skills teachers state-wide to augment the overall state science curriculum. In this way, the industrial arts curriculum is complementing the earth and space science curriculum, allowing students access to a total hands-on/minds-on educational experience. In addition, many of our schools are using maximum and minimum thermometers and rain gauges to take daily weather observations. The meteorological observations collected from school-made or purchased instruments will allow for ground-truth comparisons between observations of meteorological phenomena from earth-orbiting platforms and surface-based instrumentation, as well as provide the network of National Weather Service offices in Florida with additional cooperative stations which will have the ability to report climatological data. Several students involved in the project are already actively involved in meteorological and oceanographic studies which are winning awards at regional, state and international science fairs. In addition, extracurricular groups such as science clubs and 'exploratory' science groups are using the ground stations as a centerpiece of their activities. As a Department of Meteorology, we are now realizing the importance of EXPLORES!, as highly qualified students from high schools with these ground stations enter our Undergraduate Meteorology Degree program much better qualified to pursue the major than the typical high school graduate.

3. PRESENT/FUTURE PLANS

The project continues to grow in 1995 We are conducting numerous site visits and follow-up workshops with teachers in an effort to stay one step ahead of questions which can arise while using the ground stations. Advanced computer technology in the classroom works only if the teacher is highly motivated and interested in the approaches demonstrated, as well as in generating alternative approaches when necessary. Many of the EXPLORES! participants have demonstrated the ability to perform both, and the networking of all participants via INTERNET has allowed these teachers to share new ideas for the benefit of the entire group.

As the state of Florida embarks upon programs which increase the emphasis on environmental and natural science components for the curricula in elementary, middle and high school classrooms, meteorology becomes an increasingly effective tool for training our future scientists in concepts as basic as the scientific method, and as complex as global climate change. The EXPLORES! program strives to prepare Florida students to meet these challenges in both critical and intellectual ways.

4. ACKNOWLEDGMENTS

We could not have accomplished these tasks without the help of individuals too numerous to mention here..but you know who you are..thank you!

Support for this project is acknowledged from the TRDA under contracts #211, #309 and #401, the Title II Program of the US Dept. of Education, administered by the State of Florida Dept. of Education.

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J6.2 BRINGING McIDAS TECHNOLOGY INTO THE HIGH SCHOOL CLASSROOM

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The Man-computer Interactive Data Access System (McIDAS) is a well known research and operational videographic computer system. McIDAS software currently runs on IBM mainframe systems, several brands of Unix workstations, and IBM personal computers. The extensive meteorological data base maintained at the UW/SSEC provides the key component to exploit the system capabilities.

With the development of the PC-based McIDAS, the opportunity existed to offer these lower cost systems to K-12 educational users. For real-time use, the bottleneck of transferring large data volumes has been somewhat resolved by the expansion of the Internet and higher speed asynchronous telephone communication. Although the majority of K-12 schools do not yet have significant Internet capability, that situation should change rapidly over the next few years. A second bottleneck is free access to data. For a real-time, interactive system to be a successful visualization tool, low (no) cost access to large data bases is a key requirement.

The outstanding educational feature of McIDAS is the complete interactive nature of the system. The user starts with a blank screen and defines (creates) what is displayed. Unlike GIF viewers or Gopher/Mosaic sites, the McIDAS screen is totally created by the user, through a series of commands. This creativity is not without cost. The sheer diversity of options available to the user does not render itself to a simple graphical user interface. Although menu systems, graphics tablets and GUIs have been developed, most users who have access to the complete McIDAS data base choose to use the command line method of program execution. As an educational tool, McIDAS not only provides an excellent scientific platform to study atmospheric and other physical sciences, but also provides a platform for creative development; one does not point at an object and click, one thinks about what they want to create, develops a plan of execution and then proceeds with that plan, or a modification thereof. The creative element is maximized.

With the decrease in PC costs, the possibility of promoting McIDAS as a K-12 educational tool became possible. PC-based McIDAS systems are demonstrated at the Summer Workshop in Earth and Atmospheric Science, held for the past 3 years on the UW-Madison campus. (A poster discussing the Workshop participants and curriculum will be on display at the evening poster session.) Response to McIDAS was very positive, and in the winter of 1992-93 the UW/CIMSS and Watertown WI high school entered into a collaboration to place two McIDAS systems at Watertown, train two teachers in the basic McIDAS command structure and create the first series of education modules that provide self-instruction of McIDAS operations using a hands-on approach. In the summer of 1993 the Watertown teachers and CIMSS scientists worked to develop the first three education modules for the newly created Satellite Technology Education Program (STEP).

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TABLE 1: McIDAS Education Modules

1. An Introduction to McIDAS
2. McIDAS: The Host Mode (Connecting to and Using the Data Base)
3. McIDAS: Imaging Visible and Infrared Radiances from Weather Satellites
4. Planetary Geography Viewed from Weather Satellites (under development)

Several methods for using McIDAS in the high school were tested the first year, including daily classroom activities in an aeronautics/aviation ground school course, teaching units in physics, chemistry and geography, extra-curricular instruction by teachers in the media center (where one workstation was permanently located), and community outreach programs by teachers and students. All programs were very positively evaluated. By the middle of the school year two students were taking a McIDAS workstation to district middle schools and giving demonstrations to science classes.

Through the Summer Workshop on Earth and Atmospheric Science, a NASA grant, and the activities of UW and Watertown participants, the STEP program was expanded to include Madison area high schools. Development of education modules also continues; a project to create a global geography module for CD-ROM using weather satellite imagery is underway.

McIDAS can be brought into schools at a very low cost. If the school has a high end IBM PC to commit to the program, SSEC is providing the McIDAS OS/2 software at no-cost to STEP program participants. Thus, to use historical data (e.g. McIDAS' Greatest Hits) there is essentially no cost commitment for a school. Expansion of this program to many schools has two hurdles to overcome. The first, high speed data transfer, will be addressed with more Internet connections into K-12 schools. Currently high speed modem access means long distance calls for those schools out of the Madison area (motivating our current program to place systems in local schools). The second hurdle is low (no) cost data access. Currently, accessing the SSEC data base is "at cost"; the user pays for cpu cycle time or for data volume transferred, whichever is cheaper. For schools to use real-time data, there must be a means to provide free data. Several ways of accomplishing this are under consideration. Before a wide expansion of this program can take place, this hurdle must be cleared.

The real key to success of programs such as STEP is teacher interest in the K-12 community. There are many programs available to teachers to incorporate into their teaching curriculum, but only limited time for them to understand and learn the technology; thus it takes a significant investment of teacher time. In our experience, where teacher interest is high, many students are attracted to McIDAS, with some becoming totally absorbed with its capabilities. In Watertown, the students have taken over training neophytes and making the public presentations.

In science and education, our current and future scientific focus is broadening to examine integrated science topics. The volume of environmental data available to scientists on all space and time scales is growing rapidly, offering numerous investigative possibilities. During the EOS era these trends will increase. It is time to bring modern technical tools and contemporary scientific data to our future scientists so they can better understand key scientific issues and experience the tools used to investigate these issues. For those not entering careers in science, programs like STEP offer an enhanced learning experience to better grasp scientific principals. McIDAS offers one such possibility.

BUILDING PARTNERSHIPS THROUGH EARTHLAB

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1. INTRODUCTION

During the past decade, a number of nationally sponsored commissions have reported that the majority of American students do not fare well in sciences, technology and mathematics. Recent efforts to improve this situation have been initiated by various professional groups, including several from the earth sciences (e.g., American Meteorological Society and the American Geological Institute). Additionally, recent national attention has been directed to the "information superhighway". A need exists for making students of all ages knowledgeable about computers and the various electronic means for acquiring information. While access to this "information superhighway" would benefit education at all levels, many school districts may be unable to offer this service to all students, either because of budgetary constraints or because of the lack of adequate equipment and expertise.

Effective pre-college earth science education programs are in a position to help stimulate student involvement in science and technology. The earth sciences, in particular the weather sciences, could attract the attention of various groups of students, even those not traditionally motivated or with special learning needs. Schools could be electronically linked to each other as well as to active sources of real scientific data. Some great opportunities inherently exist for enriching science education in such an approach. However, challenging problems must be solved. Study of the planet can be fascinating, but the large amounts of information may be somewhat overwhelming to many students without adequate means for visualization. Software appropriate to the earth sciences must be designed for use on several different computer platforms. Many educational software products currently available appear to be passive in the sense that the student is asked to follow a guided sequence, answering questions with little real interaction.

To approach this opportunity and attempt to solve some of these problems, a group of earth scientists and K-12 teachers formulated an earth science education project called EarthLab, with a commitment to provide an interactive learning environment for earth science education through the use of computer technology. This report traces the formation of partnerships between educators, earth scientists and computer experts to design an effective interactive software environment and accompanying instructional packages for pre-college earth science programs.

2. HISTORY OF PROJECT EARTHLAB

EarthLab was designed to be a highly interactive and visually rich computer-based environment for K-12 earth science education which stresses student inquiry and problem solving using real data in the learning process. The name "EarthLab" was selected to convey the idea of a laboratory experience in earth science. The idea of such an environment evolved from the research of Ruth Anne Ross at Texas A&M University in the Scientific Visualization Laboratory with Dr. Bruce McCormick, one of the originators of the idea of scientific visualization.

A proposal to build the partnerships needed to create EarthLab was submitted to the U.S. Department of Energy (DOE) in early 1993. Under the request, Ross Computational Resources (RCR) would conduct a six month feasibility study and limited prototype development of the EarthLab system. Active collaboration was sought between RCR, several University of Wisconsin-Madison academic departments, a science education center and several local school districts.

Several objectives were stated in the DOE proposal to define the system requirements, to create documentation structures, to create an

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EarthLab prototype and to evaluate this prototype. Ideally, input from numerous experts with a broad range of backgrounds and viewpoints would be desirable. This group would include domain scientists, curriculum and instruction specialists, software developers and earth science teachers at the elementary, middle and high school levels. Realistically, the limited funds meant that in the initial phase of the project, active participation would mostly involve individuals from the Madison area. Newsletters were distributed to solicit ideas from various K-12 science teachers who would not be able to participate because of distance. An advisory group was formed, composed of the RCR staff, consultants and several highly motivated earth science teachers from the Madison area; a listing of these participants appears in the last section.

Throughout Phase I, regularly scheduled advisory group meetings were held. These meetings were very fruitful since they permitted the RCR staff to build a working relationship with the participating teachers and to learn from the valuable suggestions made by these experienced teachers. The teachers learned about new hardware, software and data sources that could aid them in their instructional programs. Some of the early meetings focused upon what types of equipment, software and data the teachers would like to see in their classrooms. Subsequent meetings focused upon system design.

A prototype EarthLab learning environment (see next section) was a product of these meetings. Valuable input to the design of this prototype was provided by the honors earth science class of one of the teachers. Meetings between several of the teachers and the software specialists lead to improvements in the design and ultimately, to the development of the user interface. Two exhibition/ workshops were sponsored to encourage other teachers to participate in the project. A presentation of the project was made at an annual conference of teachers and University of Wisconsin researchers. As a result of this presentation, several teachers from an elementary school in a neighboring community provided ideas and offered to help develop and test curricula that would make effective use of EarthLab.

Concurrent with the prototype development, strategic partnerships with local industry and several larger businesses were explored with a view to helping schools connect to the Internet, adding value to the eventual EarthLab product and assisting in its commercialization.

3. GOALS OF EARTHLAB

The primary concern of the EarthLab advisory group has been enrichment of earth science education through the use of current data and hands-on type activities. Consequently, the EarthLab Learning Environment emphasizes "doing science" with built-in interactive laboratory type activities (adventures) for students to solve, using real data (e.g., current weather observations). Additionally, students will be coached to pose their own research problems and then use EarthLab as a research tool to solve these problems. EarthLab will eventually provide a totally integrated earth science curriculum and environment, to allow for interdisciplinary research. As a result, EarthLab will encourage development of cross-disciplinary knowledge and skills.

The software will be designed for use on several different computer platforms. The experience of the Project EarthLab group indicates that many school districts in Wisconsin have Macintosh computers, and DOS based systems are found in a significant number of schools. The computer environment must have an easy to use interface for both the student and the teacher. This interface will include an option to allow free exploration of all available resources for reports. Printed reports and multimedia presentations can be produced from the collected data.

EarthLab intends to be network ready. Support for internetworking and experiment data management are key features to the EarthLab environment. As states commit to the information superhighway, teachers could use EarthLab as a means communicate with others as well as to retrieve real scientific data.

Obviously, the EarthLab team will not be able to produce an all-encompassing set of high quality laboratory experiences for all of the earth sciences without the active participation of a number of creative teachers. Teachers should be able to produce their own materials if they wish. During EarthLab Project discussions, it became clear that the teacher (and student) should be provided with the capability to modify existing instructional resource packages and create new ones. Therefore, EarthLab will produce comprehensive authoring tools and RCR plans to sponsor "authoring workshops" for educators who want to learn how to use EarthLab authoring effectively.

Adaptable software, flexible lesson presentation, and multimedia will also help Project EarthLab promise to insure a barrier-free learning environment. Effort will be made to accommodate the needs of those segments of the student population typically under-represented or who have special learning needs.

4. DESIGN OF AN EARTHLAB ENVIRONMENT

The efforts of the Advisory group resulted in the design of a unique EarthLab environment. Figure 1 shows the introductory screen display for EarthLab. This display will be essentially the same regardless of the computer platform. Various icons are displayed along the periphery of the main screen. The user can use a mouse driven cursor to click on these icons.

The EarthLab environment depicted in Figure 1 can be used in one of three modes: **Adventure**, **Inquiry** and **Presentation**. Because a common format is used, these three modes are operationally quite similar, but with certain differences resulting from their individual goals.

In the **Adventure** mode, a realistic problem is posed for the student to solve. Since these problems could entail teacher produced laboratory exercises, the teacher will be able to exercise some degree of direction and control of the various data and information resources that the student will investigate in solving the particular problem. Several completed Adventures are to be included in EarthLab to demonstrate the system and to assist teachers with further development of their own Adventures. EarthLab is designed to permit individual authoring of Adventures. Some of the suggested EarthLab adventures include:

EarthLab Adventures (Solving a given problem)

Weather Adventures (Is a storm coming?)
Climate Adventures (Where should I live?)
Water Adventures (Locate a home-site)
Mapping Adventures (Where am I?;
    Find my way home)
Prospector Adventures (Mineral Find;
    Energy Find)
Environmental Adventures (Landfill adventures;
    Nuclear accident; Oil spill clean-up)
Astronomy Adventures (Check out the
    habitability of Mars)
Ocean Adventures (Deep dive and ocean trench;
    Investigate the mid-ocean ridges)

The **Inquiry** Mode is the part of the EarthLab environment where the student proposes a problem, designs an experiment and works toward a plausible solution through appropriate exploration and research. This Inquiry mode differs from the **Adventure** mode only in that Inquiry mode is more open-ended. EarthLab will carry a substantial library of information in scientific databases; additionally, as real-time data become more readily available, a combination of live data plus archived information will provide the basis for more complex problem solving.

Presentation Mode, the third mode, can be used in conjunction with either the Adventure or Inquiry modes. In the Presentation mode, the student or teacher will be able to utilize various graphical and other resources to create and present a multimedia report. This report may be a list of answers made by the student working in the Adventure mode, or a presentation produced as an outcome of the Inquiry mode. The finished report can be printed, used in an organized slide show presentation, or saved to videotape.

5. IMPLEMENTATION

The prototype instructional packages that have been assembled and demonstrated to teachers include a unit on weather observation, complete with an icon-driven "toolbox" of weather instruments or observation platforms (e.g., thermometers, barometers, radiosondes and weather satellites). A hypertext layer describing these instruments has been included. Access to these weather instruments and pertinent background information from other weather units is not only possible but encouraged as part of the emphasis upon active student inquiry. Another unit describing weather charts, analyses and satellite images has been produced.

6. FUTURE PLANS

The EarthLab team is discussing collaboration with potential partners in industry and government in order to continue development of EarthLab. A weather calculator, designed to be an integral part of the meteorological portion of EarthLab may be made available as a "stand-alone" tool for a hand-held computer. Additional weather related instructional packages are being contemplated.

7. CONCLUSIONS

Enriched by the partnerships, the formative phase of the EarthLab Project provided a learning experience for all participants. For some of the staff of RCR, contact with teachers revealed that while attractive software is important, a set of definitive instructions, organized curricula and explicit lesson plans are needed to allow teachers the opportunity to utilize the units more effectively. In other words, continuing teacher input is essential. Contacts with software designers permitted the teachers to explore various computer systems and software packages. Furthermore, while teachers may have to cope with existing curricula and computer equipment, they should be encouraged to "invent" the future, with new curricula and equipment. The RCR staff and teachers both became aware of numerous data sources from domain scientists. Many inexpensive data sources pertinent to earth science education are available electronically, if the teachers can obtain ready access to the information superhighway.

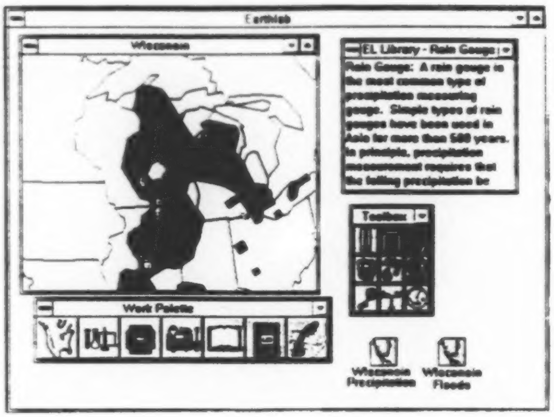
8. PROJECT EARTHLAB PARTICIPANTS

Numerous people and organizations have directly or indirectly assisted RCR in developing EarthLab. The involvement of these dedicated experts is valuable and essential. Several teachers have volunteered their time to provide insight. Among them are Tom Adas (Verona High School), Ben Senson (James Madison Memorial High School in Madison) and Ron Welhoefer (Madison East High School). Lois Kelso (Belmont High School in Laconia, NH) has contributed her experiences with reading disabled students to the project's commitment to special student populations. Science teachers from the Cottage Grove Elementary School (Monona Grove School District) have joined the EarthLab Project to offer their help in designing and evaluating prototype systems. Discussions were held with Bruce Smith of Appleton West High School, the Project Atmosphere AERA for the state of Wisconsin concerning the development of a district wide weather observation network which would be linked electronically.

Dr. Gary Lake, a valuable consultant in all phases of the EarthLab, is Program Director of the Center for the Advancement of Science, Mathematical, and Technology Education of the Wisconsin Academy of Science, Arts, and Letters. Don Vincent, earth science educator and president of ESRA, offered his perspective on requirements for EarthLab.

The UW Space Place, a public-outreach educational facility operated by the Space Astronomy Laboratory of the University of Wisconsin-Madison, has been the site of two RCR/Project EarthLab exhibitions. It also served as the meeting place for the Project EarthLab team. On-site at the Space Place, RCR placed a DOS computer, a large television monitor, and a Silicon Graphics computer for advanced scientific visualization development. The Director of the Space Place, Kathy Stittleburg, is on the EarthLab steering committee.

The Department of Atmospheric and Oceanic Sciences at UW-Madison was also a sponsor. Encouragement has come from the departmental chairman, Professor David D. Houghton, long an advocate of quality science education and of university out-reach programs to K-12 levels. Dr. Houghton is currently President-elect of the American Meteorological Society.



Rain Gauge: A rain gauge is the most common type of precipitation measuring gauge. Simple types of rain gauges have been used in Asia for more than 500 years. In principle, precipitation measurement requires that the falling precipitation be

Figure 1. An Overview of the EarthLab Learning Environment.

J6.4

A COLLABORATIVE INTERDISCIPLINARY UNIT ON WEATHER FOR ELEMENTARY EDUCATORS ON THE INTERNET

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1. INTRODUCTION

Educators increasingly are looking to the Internet for resources and collaboration with colleagues as more schools have access to the network. To help meet the needs of these educators, we are developing an Internet-based Thematic Unit Archive (TUA) which will house thematic unit lessons accessible to and contributed by educators. A thematic unit is a collection of lessons spanning many disciplines utilizing a common theme or topic. In a thematic unit the focus is on a topic of interest to students rather than traditional school subjects such as reading, writing, and math [Gamberg, 1989]. The advantage of a thematic unit is that a topic can be studied in-depth, incorporating relevant lessons from traditional school subjects to approach the topic from a variety of perspectives. The intent of the TUA is to create a forum by which educators can share unit and lesson ideas among themselves and with "experts in the field" via the Internet. The asynchronous collaboration on lesson submissions and modifications creates an evolving educational resource which will grow in scope and quality.

We foresee the need to distribute text, images, occasionally sounds, and other multimedia elements as shared resources comprising the thematic units. We chose the application Mosaic which was developed at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign as the primary tool for the TUA. Mosaic facilitates the sharing of information on the Internet by providing a unified and intuitive interface to the various protocols, data formats and information available on the Internet [Andreesen, 1993].

The first thematic unit developed for the archive is a weather unit intended for elementary grade levels. The weather unit is a collection of Mosaic documents including classroom lessons on a variety of subjects, experiment descriptions, stories, student journal pages, literature reviews, games, extracurricular activities, and more. A user accessing the weather unit through the TUA can post comments either within the archive to comment on the curricular material contained on the archive or within the weather unit to suggest modifications or additions to a particular lesson.

2. THEMATIC UNIT ARCHIVE

The thematic unit archive provides educators a forum to share knowledge, expertise, resources, and lesson plans. Lessons available on the archive can be evaluated as they are tried in the classroom. Through the comment board available in the TUA, the educators can make suggestions to improve the lessons. The Mosaic link to the TUA is:

http://faldo.atmos.uiuc.edu/TUAHome.html

Collaboration between educators will result in a continuous infiltration of new ideas providing tools to present the same concept through multiple teaching methods and from various perspectives. Because the TUA is an Internet tool, collaboration will include access to experts in many fields who may comment on the validity of the concepts explored in the lessons as well as suggest alternative teaching strategies. Internet access will provide educators, even in remote locations, the ability to use and contribute to the TUA. The TUA may particularly benefit those teachers with less experience through collaboration with experts and more proficient educators.

2.1 TUA Structure

The thematic unit archive consists of a series of Mosaic documents which reside on a central computer server. Any of the text, images, or sounds contained in a document may act as a hyperlink connecting the document to information located anywhere on the Internet. The portion of text or image designated as a hyperlink is generally highlighted and can be activated by selecting with a mouse. When the hyperlink is activated, Mosaic automatically retrieves the remote document from its origin on the Internet and displays the hypermedia using the appropriate display application. We utilize this funcionality provided by Mosaic to simulate an archive by creating a centralized access point to the local as well as the remote information which comprise the thematic unit archive.

Figure 1 shows the structure of the TUA. The top level of the TUA contains a list of grade levels (preschool through twelfth grade) which are hyperlinked (solid lines) to lists of thematic units for that grade level. Each thematic unit is composed of several subject areas with lessons linked to the appropriate subject area(s).

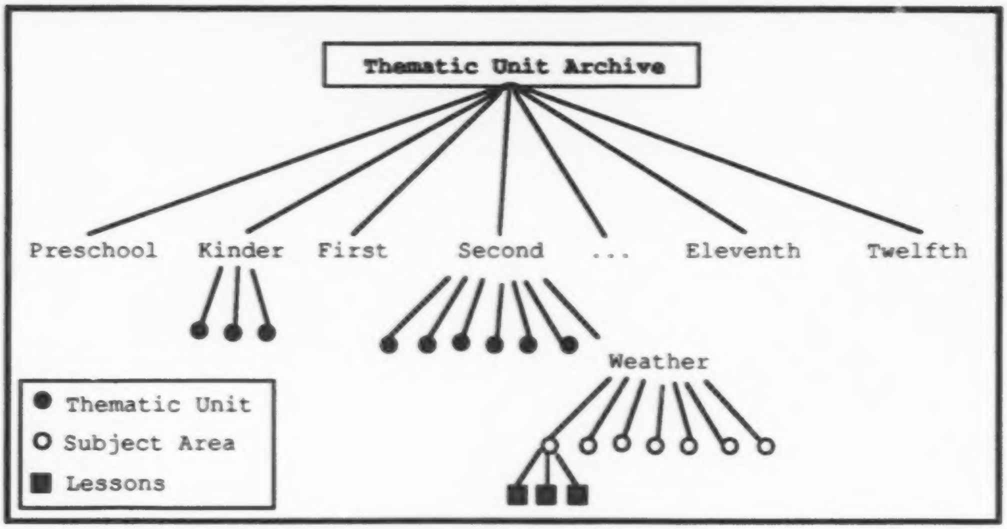

Figure 1. Structure of the Thematic Unit Archive

3. THE WEATHER UNIT

We chose weather as the subject of our introductory unit because it is well suited to the interdisciplinary concept of the thematic unit. In addition, weather has many math and science applications which are areas of national educational weakness [Fitzsimmons, 1994]. Students can easily relate to most of the concepts presented because they experience weather everyday and often enter the classroom with an interest in severe and unusual weather phenomena.

The weather unit currently is targeted for educators of second to fourth grade but concepts can be expanded or simplified for other grade levels. Our philosophy in developing this unit is that the basic concepts should be teachable to any grade level provided the appropriate techniques and language are used. The lessons encourage the students to explore and experience the concepts through "hands-on" activities, cooperative learning and personal discovery.

3.1 Weather Unit Structure

The weather unit is organized into twelve subject areas. The subjects are listed in Table 1, as are the number of lessons for each subject. Initially, there are a total of nineteen lessons written for the weather unit. The interdisciplinary lessons are cross-listed under multiple subject areas.

TABLE 1

Subject	Number of Lessons
Art	3
Classroom Props	1
Drama	1
Geography	2
Math	1
Music	2
Reading & Writing	4
Resources	5
Science	13
Social Studies	2
Trips	0

Many lessons contain hyperlinks to other lessons. Often the links connect lessons contained in the same subject areas. For example, in the Science subject area the lessons Evaporation, Condensation, and Precipitation are connected to each other and to the unifying lesson of the Water Cycle. The connectivity between lessons is not limited to lessons in the same subject area, however. For example, the Water Cycle lesson (under Science) is linked to several lessons in other disciplines such as Art, Reading, and Physical Education. This interdisciplinary approach is favored by many educators because the format provides a variety of educational perspectives on the concept.

Figure 2 shows the interdisciplinary nature of the weather unit. For every lesson which has one or more hyperlinks to another subject area, a thin line is drawn between the subject areas in the schematic to represent the link(s). In most cases, the links are found in the Prerequisites, Follow-Up, and Evaluation sections of the lessons.

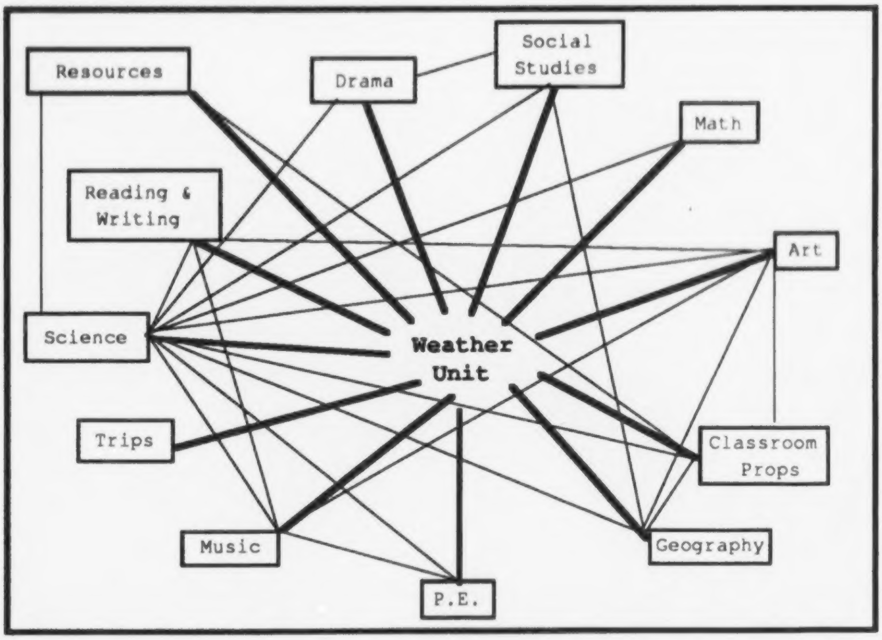

Figure 2. The Weather Unit Web

The web-like structure of the weather unit precludes any predefined starting and ending points to the unit. This makes it possible to extract and teach only portions of the unit when needed. For example, an educator working on a lesson on nocturnal animals may decide that an educational excursion into the explanations for night and day may augment the nocturnal animal lesson. He or she can enter the web structure directly to the night and day lesson. From here it will take only a short time to survey the prerequisites and follow-up lessons to determine what will be involved in teaching the night and day concept.

A student weather journal is included as part of the weather unit. The pages of the journal are included as hyperlinked documents embedded within the lessons. The documents can be printed and distributed for the student's use. The journal provides a work area for students to record daily weather observations, experiment results, personal writings and illustrations. The weather journal can be reviewed periodically by the teacher as a portfolio assessment.

Another tool included in the weather unit is a Literature Review section found under Reading and Writing. The reviews consist of bibliographic information and a brief summary of each book. We provide personal opinions and ratings of the book content and illustrations as well as special notes when the accuracy of the book content is in question. The Literature Review section is intended to be collaborative so that TUA users can submit summaries and opinions of books they have reviewed or used in their classes, as well as read the reviews and summaries of previously posted by others. As the Literature Review section grows it will facilitate access to books on specialized topics and provide some subjective guidance to the quality books.

The Resource section of the weather unit gives additional information about contacts which may assist in the teaching of the unit. Examples of resources include: locations to order supplies and materials, museums that have educational material available, experts in the field, and universities and libraries that can supply additional material and information.

3.2 Lesson Structure

For the weather unit lessons, we chose to utilize a standard lesson format. The section headings and descriptions for each lesson include:

Prerequisites: Includes concepts that prepare students for the ideas to be presented in the lesson. Some of these concepts are hyperlinks to lessons found elsewhere in the unit.

Objectives: Describes the educational goals of the lesson.

Materials: Lists the materials required for the lessons; some of these are hyperlinked to documents in the Resources section of the unit.

Introduction: Includes brief stories, discussions, or short experiments to engage the students in thought about the concept being taught.

Body: Contains the main experiments and demonstrations used to guide the students to an understanding of the concept.

Conclusion: Summarizes the concepts taught in the body through discussions, writings, and/or games.

Follow-up: Includes concepts which relate to the idea taught in the lesson. Some of the concepts are hyperlinks to other lessons in the unit.

Evaluation: Games, writings, tests, and/or discussions used to determine the student's understanding of the concepts taught.

4. COLLABORATION

The strength of the Thematic Unit Archive lies in the contributions and collaborations by the users. In August 1994 the Thematic Unit Archive and the weather unit were released to the public and introduced to a group of thirty teachers attending an Internet Workshop at the National Center for Supercomputing Applications. After the attendees explored the archive we held a discussion and took a written survey of their comments. The initial comments regarding the thematic unit archive were positive and the users proposed a series of workshops for educators to submit and evaluate thematic units for the TUA. Also, the possibility of establishing a peer review process was discussed. The comments on the weather unit centered around the appropriate level of detail for the individual lessons and more stringent student evaluation techniques which may address state requirements.

Statistics were compiled for the first month after release to the public. There were a total of 1,153 accesses to the TUA and the weather unit during the month of August 1994. About 75% of the accesses were from the educational community. The remaining accesses were divided between governmental, commercial, and foreign users. The lessons on urban data visualization and the relationship between sunlight and temperature were accessed the most, perhaps because they were cross listed in several different subject areas and encountered more often by users traversing the unit web.

5. SUMMARY

The weather unit as it was released to the NCSA workshop was intended to be a prototype collaborative thematic unit. The workshop and the user comments to date have provided feedback which will help to improve the weather unit and the TUA. As the TUA continues to get exposure, we expect this collaboration to continue and the TUA to grow into a rich resource for the educational community.

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J6.5 CoVis: A National Science Education Collaboratory

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1.0 Introduction

Human interactions have largely been shaped by physical space. Except for a few technologies like the telephone, fax and perhaps electronic mail, the way we work, learn and play has been constrained by geography. This will change with the National Information Infrastructure (NII) as it creates a new "place" for human activities. This confluence of computing, communications, and networking technologies is expected to touch all aspects of American life. What will the NII mean to schools and learning communities, for science education and teacher development?

There is not one answer. Just as school buildings and the communities they house are shaped by factors like population density, local economy, and prevailing views of pedagogy, the NII will take shape in learning communities in diverse ways. No single research and development effort can be a model of all of these. The Learning Through Collaborative Visualization" or more simply, CoVis, is an NSF-NIE testbed that focuses on how to use applications of high performance computing and communications technologies (HPCC) to support science education reform. CoVis is centered at Northwestern University and UIUC's Department of Atmospheric Sciences is a key participant in CoVis development. The CoVis community includes teachers and students, research scientists, museum-based informal science educators, and science education researchers, in a "distributed multimedia learning environment" (Pea & Gomez, 1992a).

The CoVis philosophy is grounded in a constructivist approach to science learning and teaching that emphasizes authentic, challenging projects as the nucleus of activities for "learning communities" which include students, teachers, scientists, and other participants. The goal is to create learning communities that more closely resemble the collaborative practice of science, which increasingly relies on HPCC technologies to create "collaboratories" (Lederberg & Uncapher, 1989). In CoVis we have been using HPCC to support the formation and work activities of learning communities with media-rich communication and scientific visualization tools in a highly-interactive networked collaborative context (Pea & Gomez, 1992b; Pea, 1993). CoVis has focused on three areas—project-enhanced science learning, collaboration, and scientific visualization—as means for transforming science education. In this process, we have worked with high school teachers in development activities to transform their classrooms from traditional teacher-centered classes to project-enhanced classes in which students learn about science through personal and group inquiries.

2.0 CoVis Network

To bring the practices of science to classrooms, the CoVis network extends today to Evanston Township High School (ETHS), New Trier High School (NTHS), Northwestern's School of Education and Social Policy, the Department of Atmospheric Sciences at University of Illinois, Urbana-Champaign (UIUC) and the Exploratorium Science Museum. The network enables high school students to join with other students at remote locations in collaborative groups. Students also use the network to communicate with university researchers and other scientific experts in teleapprenticing relations. Our experiences in constructing a collaboratory highlight *system integration* and *new software design and implementation in classrooms*, two challenges that will face all National Infrastructure for Education (NIE) testbeds and other NII efforts.

One major goal of the CoVis project is to combine prototype and off-the-shelf applications to create a reliable, networked environment that showcases HPCC technologies for K-12 learning communities. Our key result is that the network is running and in daily use by approximately 300 people, mainly high school students. The challenge of this effort has been to take a collection of technologies, many only demonstrated or tested in small-scale lab and demo situations, and place them into daily service in demanding conditions. Our progress culminated in a stage-by-stage installation during Fall 1993 of the CoVis network testbed using public-switched ISDN services.

The network design and implementation is the result of intensive collaboration between Northwestern, Ameritech, and Bellcore, and it uses the Primary Rate Integrated Services Data Network (PRI-ISDN) as the transport layer for the CoVis network. In the immediate term, ISDN is the network service that offers the best combination of high bandwidth and ubiquity in a switched service. Bellcore predicts that by 1996 more than 70% of the nation's population will have access to

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ISDN service. A key benefit of ISDN for the CoVis Project is that its bandwidth can be broken up into call channels, which can be dedicated to different functions. We used this feature to create a two-function "overlay" network that gives student workstations access to both ethernet-based packet-switched data services and circuit-switched desktop audio/video conferencing. One group of 6 64 kb/s ISDN channels is being used to create a virtual ethernet to each school running at 384 kb/s. With compression, this network has a performance close to 1 Mb/s. Other channels provide 384 kb/s switched video teleconferencing for each of the CoVis workstations in the schools. Since ISDN is "public switched service," CoVis participants can, in principle, place calls to any other ISDN line in the country.

Within each school, the CoVis network supports synchronous and asynchronous communication. The CoVis Project supplied each school with five workstations per classroom plus one workstation at an alternative location for student access outside classes. All workstations are connected to an ethernet which is bridged via ISDN lines to the Internet. The CoVis communications and collaboration suite includes the Collaboratory Notebook (see below), e-mail, file transfer, Usenet news (filtered for suitability), and access to the World Wide Web.

In addition to these applications, the communications suite includes *screen sharing* and *video teleconferencing*. CoVis participants may collaborate synchronously through screen sharing, in which one user can see exactly what appears on the screen of another user, even though at a distance, using the commercial application Timbuktu, produced by CoVis' industry partner Farallon Computing. Desktop video teleconferencing is another critical element of the CoVis testbed, and examinations of its utility for learning and teaching are a key part of our research. Students use the Cruiser™ application, provided by Bellcore (Fish et al., 1993), to establish video teleconferencing calls. Cruiser allows students to place calls, both point-to-point and point-to-multi-point, to other CoVis addressees by selecting the name of the individual(s) from a directory. Cruiser is a client application of Touring Machine, the network management software developed by Bellcore (Bellcore Information Networking Research Laboratory, 1993) which manages the heterogeneous resources (e.g. cameras, microphones, monitors, switch ports, directory services) in the CoVis network. It is significant that CoVis Project needs and Ameritech (one of the baby Bell companies) interests drove the first integration by Bellcore of Touring Machine into an ISDN network. To our knowledge, CoVis is the first school-based application of ISDN desktop video conferencing.

3.0 CoVis Testbed Components

The CoVis testbed seeks to provide students with authentic scientific inquiry experiences across geographically dispersed sites. To succeed in this endeavor, it has been necessary to develop two new application environments: (1) a groupware application to support collaborative student inquiry, and (2) tools to make scientific investigation techniques, specifically data visualization, accessible to high school students.

Collaboratory Notebook. The Collaboratory Notebook is a central and unique element of the CoVis environment, serving several roles for project-enhanced science learning (Edelson & O'Neill, 1994). Briefly, the Notebook is groupware for scientific inquiry. It is a shared, hypermedia database built on top of an Oracle database connected to the Internet. The Notebook provides a place for students to record their activities, observations, and hypotheses as they work on projects. It provides a means for planning and tracking the progress of a project and for collaborators to share and comment upon each other's work. Within the Notebook, there is a small, fixed set of page and link types. These types provide a scaffold intended to assist students in structuring their open-ended inquiry process. For example, a page that records a set of visualization activities can be linked to questions raised during those activities. Those questions can, in turn, be linked to conjectures that address the questions, and to plans for investigating the questions. The goal of the Notebook is to provide students with a "scaffolding structure" for open-ended scientific inquiry, and a mechanism for collaborative work within or across schools.

Scientific Visualization Environments. Today atmospheric and other scientists use data visualization tools and work with standard data sets routinely (e.g., Searight et al., 1993; Wilhelmson, 1994; Wilhelmson et al., 1994). These tools and data sets are mainly useful to highly specialized members of technical communities (Gordin & Pea, in press). To allow students to work with the same data sets as scientists in similar ways, we have adapted the tools used by atmospheric scientists to be appropriate for high school students. To date, CoVis has developed two such visualization environments, The Climate Visualizer and The Weather Visualizer, and is developing a third, The Greenhouse Effects Visualizer. All three visualization environments are tightly integrated with the Collaboratory Notebook.

(1) The **Climate Visualizer** allows students to construct scientific visualizations to explore global climate patterns (Gordin, Polman & Pea, in press). It contains 25 years of twice daily weather values (temperature, pressure, and wind) for most of the northern hemisphere. In the Climate Visualizer, temperature is encoded as a raster color image, altitude as contours, and wind as arrows (or vectors), with an optional overlay showing continents. Students can interactively sample values in a visualization by selecting locations with a mouse and can view trends across time by subtracting one image from another. For example, seasonal differences can be seen by subtracting January temperature from July. Such a visualization might highlight the differing properties of land and water in absorbing heat. The Climate Visualizer is a front-end to Spyglass Transform, a commercial visualization

package, and uses a data set available on CD-ROM from the National Meteorological Center's Grid Point Data Set.

(2) The **Weather Visualizer** (Fishman & D'Amico, 1994) is a tool for examining current weather conditions throughout the U.S. in the form of: satellite images in visible and infrared spectrums; customized weather maps displaying up to 14 different variables at five different altitudes for any region or city in the U.S. at a variety of zoom factors; "six-panel images" displaying temperature, pressure, wind speed, wind direction, dew point, and moisture convergence for the entire U.S.; and textual reports providing local conditions and local and state forecasts for all reporting stations. The Weather Visualizer is implemented as a front end to wxmap, a UNIX program developed at the University of Illinois. The data for the Weather Visualizer currently comes from our collaborator University of Illinois' Weather Machine, which, in turn, receives data from the National Weather Service's Family of Services DD+ feed and from GOES satellites (Ramamurthy et al., 1992). Through its gopher server for current weather images and information, the Weather Machine at UIUC is providing a valuable service to a community well beyond K-12, including researchers and educators nationwide. Over 100,000 requests for images and text are received per day in peak usage periods (Ramamurthy & Kemp, 1993; Ramamurthy et al., 1994; Ramamurthy & Wilhelmson, 1993).

(3) The **Greenhouse Effects Visualizer** (Gordin, Pea, & Edelson, 1994) coordinates a collection of data sets that include the sun's incoming radiation (insolation), the amount reflected by the earth (albedo), the temperature on Earth's surface, and the earth's outgoing radiation, to allow students to examine the balance of incoming and outgoing radiation for the earth (Greenhouse effect.)

Multimedia Modules In addition to providing real-time weather information, one of UIUC's main contributions to CoVis has been the development of an array of Internet-accessible multimedia instructional modules, consisting of text, color diagrams, movies, audio, and scanned images, that introduce and explain a variety of important concepts in atmospheric sciences as they arise in project inquiry. These multimedia instructional modules on various topics are being developed for use at the high school level, and are available from *The Daily Planet™* server, A Web server at UIUC. The modules are being tested at the two current CoVis schools in the Chicago area, and they are being revised and refined based on the feedback from them. Such multimedia-based instruction provides an alternative approach to learning, one in which the student, through interaction with the computer, becomes actively involved in the learning process.

The first set of modules that has been developed describes pressure and wind, various types of weather maps, satellite and radar images, and their use in weather analysis and forecasting (Ramamurthy et al., 1994, Sridhar et al., 1994). Through the use of colorful diagrams, video clips, text, and audio narration, a student becomes acquainted with topics like pressure, high and low pressure centers, and the balance of forces that generate winds. CoVis teachers at the two Chicago-area schools incorporate appropriate resources from these modules and our online weather databases into their courses. Other modules currently under development include a: (1) Cloud Catalog, (2) Guide to Atmospheric Optics, (3) Tornado Spotters Guide, and (4) Severe Storms Guide. The Tornado Spotters Guide, in addition to informative text and graphic inserts, contains clips of live tornado footage. The ultimate goal is to deliver extensive and broadly useful multimedia resources over the Internet, to support very diverse project inquiries. The multimedia modules are not only improving education at the K-12 level by making it more interactive through the use of advanced computer technologies, but are also providing a collection of curriculum resources for the whole Internet community.

4.0 Use of the CoVis Tool Suite

CoVis technology is in daily use by the entire community. A measure of use can be provided by a look at application uses: From Jan-Mar 1994, CoVis school-based users launched approximately 14,000 applications. The overwhelming proportion of use is of Internet tools (e.g. e-mail, Gopher) at 59%, with an additional 13% representing CoVis tool launches (e.g. Collaboratory Notebook, Climate Visualizer, Weather Visualizer), 13% graphic tools, 8% word processors or spreadsheets, and 7% utilities and games. The CoVis community has not had time to develop well-defined patterns of tool use, but early impressions are that CoVis applications are very popular and may increase in use percentage with familiarity. Video conferencing was introduced to students mid-January '94. We found considerable increases in HPCC uses for the student population from Fall 1993 to Spring 1994.

In its ongoing research, the CoVis Project studies and reports on the design, implementation and use of these network-based and media-rich learning environments for an audience of learning scientists, educators, educational telecommunications policy analysts, and corporations who are defining "new media" applications and services. CoVis is examining pedagogy and technology questions such as: How should next-generation information networking be implemented to spur science educational reform? What are proper educational support roles for networked multimedia technology, desktop videoconferencing, and other next-generation communication and computing technologies? What are the details of a pedagogy which will support diverse communities of practice? How can today's teachers transform their work-roles in new learning environments? What new curriculum materials and tools will be needed to support revitalized science curriculum that keeps pace with developments in the sciences and changes in the national information infrastructure?

5.0 New Developments in CoVis

To significantly scale the CoVis testbed over the next three years, we have developed strategies for realizing the innovative concepts and benefits of the CoVis broadband technology approach for a spectrum of schools with very different levels of technological readiness and infrastructures. We have defined three levels we describe in terms of a Technology Pyramid. Each level corresponds to a specific richness of technology infrastructure. At Level 1, the Pyramid's apex, will be a relatively small number of schools with the complete suite of CoVis technologies, including new applications and services to be developed. Moving down the pyramid, ,Levels 2 and 3 represent increasingly larger numbers of schools, requiring successively lower levels of technology infrastructure. Our goals are to include as many schools as possible to leverage use of the more common levels of installed technology in our testbed, and to define affordable entry levels for migration paths to higher levels of the pyramid. The levels are not rigid but serve as a realistic representation of the spectrum of schools that will come to join the NII. Schools will migrate across levels in both directions and combine different capabilities within a building. Including schools at these diverse technology levels will enable us to provide key data concerning the cost-effectiveness of the different levels for educational networking connectivity for science education reform outcomes.

At the top of the pyramid representing our Level 1 sites, we will intensively work with a few schools but increase their number and diversity from our current 2 suburban Chicago schools (involving 12 classes) to six total schools by 1996-97. These schools will include urban, suburban, and rural sites and will cross states. In six Level 1 schools, we will continue exploring high-end HPCC technological infusion and implementation for schools at the cutting-edge (below). The considerable diversity of new sites at this level will help us to understand the challenges and particular benefits of adding high-bandwidth connections to schools in different types of communities, since their technical suite will approximate the current CoVis school profile: broadband data connections to the Internet (384Kb/s or better), and at least three desktop videoconference stations per school.

Schools at Level 2 of the pyramid will have similar data networks to Level 1 schools except for desktop video conferencing and video server access. However, through ordinary phone lines and screen-sharing, Level 2 sites can participate in audio teleconferencing and will have access to all CoVis software and materials via the Internet. Schools at Level 3 will have low-bandwidth connections to the Internet, via dialup, and will represent the typical network connection paradigm for U.S. schools today. Through SLIP or PPP protocols, they may access CoVis software and materials on the Internet, but will not have any form of synchronous conferencing. To support these Level 3 schools, we will be developing and distributing video tapes and CD-ROMs to help them take advantage of the materials/pedagogy we are developing throughout the CoVis Collaboratory testbed.

In adding new functionalities to the Collaboratory over the next three years, as described below, we seek to build on the existing CoVis network architecture in order to extend the range of ways that students, teachers, and other members of the community can communicate and collaborate with each other. In building and extending the CoVis technology infrastructure, our challenge continues to be taking innovations that have been used in limited ways in research tests and demonstrations and placing them into service so that they can reliably serve the needs of a demanding population.

(1) Software Environments to Support Collaboration. In the early years of the CoVis Project we have developed an architecture for collaboration that combines the Collaboratory Notebook, specially-developed software for collaborative inquiry, video conferencing, remote screen sharing, and a standard package of Internet tools. In the next several years, we will continue development of the Notebook as we extend from a single community of 12 classes to multiple communities of thousands of classes. This will involve, for example, the development of "libraries" of notebooks that will allow students to locate relevant prior work by other students through easy-to-use search mechanisms. In addition, it will be necessary to provide easy administration of the Notebook to school personnel. This goal will be achieved in collaboration with the National School Network Testbed Project at Bolt, Beranek & Newman (BBN) in Cambridge, Massachusetts. We will migrate the management of user accounts for the Collaboratory Notebook to BBN's Copernicus server, which already supports many important administration functions for schools.

(2) Enhanced Video Conferencing Services. Today our video conferencing network is used for point-to-point video calls. As part of our new work on the CoVis testbed, we will have multi-point video conference calls available. This ability to involve participants in a variety of locations in a single call lets us extend how the video network is being used to include two telepresence experiments.

(3) Video server. The CoVis video server will allow users to both view and record digital video in real time. Unlike current networked applications such as Gopher and Mosaic, the users will not have to download compressed video to the local workstation before viewing it. Instead, the video will be streamed live between the video server and the user's workstation, in either playback or recording modes. The video server will be supported by StarWorks™, a video applications server produced by industry leader Starlight Networks (Mountain View, CA).

(4) Geosciences Server. A multi-institutional design will be developed and implemented for a World-Wide Web Server for Geosciences Education to include tools, datasets, and diverse multimedia materials for use in K-12 science education involving the earth, atmosphere, and environment. Initial contributors to design and materials available over the server nodes will include Northwestern, UIUC, U. Michigan, U. Colorado, Exploratorium Museum, and select schools. Materials will include: datasets, editorially-reviewed student projects in Collaboratory Notebooks, directory services for participants, and a comprehensive indexing scheme. We will seek to assure compatibility of testbed science curriculum resources and activities with the leading state frameworks and national science education standards. This same server will provide the major dissemination vehicle for the project, and will include publications, papers, reports, images, animations, and brief QuickTime video clips to share its results on an ongoing basis with a broad community. For Level 1 schools that have video conferencing capability, the Geosciences Server will provide an interface to materials on the video server.

The ultimate goal of the server is to develop a new paradigm for Environmental Sciences education. Our consortium will develop an on-line weather laboratory, to provide interactive access to a wide range of weather information. An important aspect of the server is that it will provide access to observations, local forecasts, watches and warnings, satellite images and numerical model forecasts from any computer that is connected to the Internet. Not only will any computer on the Internet have access to the server, but we will also structure the information such that others who create their own servers can follow our model in setting up servers that point to ours.

The educational and informational material on the server will initially be focused on atmospheric sciences but will grow to include a broad range of earth science topics. One section of the server will be devoted to weather. The access to up-to-the-hour weather data that is currently available through CoVis Weather Visualizer will be augmented with historical data that covers recent years at daily or twice daily intervals and that covers major weather events during those years at hourly intervals. A second section of the server will be devoted to climate. An example of the resources to be available there is information drawn from the Midwestern Climate Atlas, which was recently prepared by the Midwest Climate Center at the Illinois State Water Survey. The statistics in the atlas include temperature, rainfall, snowfall, and extremes and probabilities of occurrence. In addition to these primary climatic elements, the atlas includes a variety of other derived variables such as heating; cooling; and growing degree days, growing season length, and frost dates. Most of the development of the server and the resources on it will be conducted at UIUC with close consultation on pedagogical matters from team members at Northwestern and the Exploratorium.

The server will also contain Exploratorium-produced Video Answers to FAQs (frequently asked questions). These will be produced multimedia responses to questions on geosciences created using Exploratorium resources (exhibits, materials, media) that are distributed on demand from Exploratorium World Wide Web and the CoVis Geosciences Server. These Video FAQ's will also be available for real-time viewing through the CoVis video server. This material will be developed based on participation in the Collaboratory activities and from responses from teachers and students. In addition, a video introduction to the museum will be available for the users to help them understand what they can get from the Exploratorium and to give a personal introduction to the museum and staff.

To increase the level of interaction between atmospheric scientists and CoVis students, UIUC will be conducting daily weather briefings via the Cruiser videoconferencing system to CoVis sites. These weather briefings will be tailored to the CoVis community, and offered by UIUC faculty and students. During these video weather briefings, we will illustrate, through interpretation and analysis of weather charts, satellite and radar animations, and forecast products, key concepts that will enable a student to conceptualize the structure and dynamics of the atmosphere. Students may also participate in discussions of weather processes as depicted by weather maps, and learn techniques of forecasting weather. The depiction of atmospheric kinematic and dynamic processes on weather charts will be emphasized. We plan to record and digitize some of the weather briefings and eventually make them available to the CoVis sites and explore the use of video server technologies in instruction and collaboration. Such video servers are currently under development at several places, including NCSA at University of Illinois, Urbana-Champaign.

6.0 Concluding Remarks

CoVis envisions widespread use of learning environments where next-generation communication and computing technologies enable students, teachers, scientists and other professionals to work together in networked communities focused on science education. Today CoVis is a small-scale working model of this vision in two high schools. in the next phase of the CoVis Project, we are poised to provide some of the key national research and development required to inform large-scale and cost-effective implementations of reform-oriented science educational networking. There are over 18,000 high schools and 12,000 middle/junior high schools in the nation. We will be developing and researching the CoVis testbed as a *National Science Education Collaboratory*, by systematically addressing the scaling issues inherent in achieving goals of *critical mass* of participation and in *diversity* of schools, teachers, students and other participants in such an enterprise. In addition, CoVis is expected to grow from a venue for addressing research and development questions to an experimental facility for informing governments and businesses about how to do the large-scale implementation of HPCC technologies within the NII in a cost-effective manner that meets the reform needs of school communities.

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J6.6 *The Daily Planet™*: An Internet-Based Information Server for the Atmospheric Sciences Community and the Public

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1.0 Introduction

The availability of information about the behavior of our atmosphere and about atmospheric science activities on the Internet is of growing importance in making progress in both our understanding of the atmosphere and in weather forecasting. It is also of substantial value to the general public, particularly in informal and formal educational settings, providing access to current as well as historical information in a timely manner and stimulating curiosity in the behavior of the atmosphere. Beginning in the early 90's, we began to develop Internet-based resources for the atmospheric science community that include the popular University of Illinois (UofI) Weather Machine accessible through Gopher and more recently *The Daily Planet™ (TDP)*. The latter is accessed through NCSA (National Center for Supercomputing Applications) Mosaic software, which is based on World Wide Web (WWW) technology, and includes access to the Weather Machine. *The Daily Planet™* is becoming a full-scale Environmental Information Server that will provide transparent access to meteorological, climatological, hydrological, and Earth Observing System (EOS) databases, multimedia educational modules, distributed archives of data sets (both real-time and retrospective), and other Internet-based resources.

2.0 The Weather Machine
(gopher://wx.atmos.uiuc.edu)

The Department of Atmospheric Science at the University of Illinois has a proven track record of providing earth and space sciences data to the public. In the initial implementation of its weather distribution system, raster image products were created and made available, along with textual information, using the X-window System software to any computer or terminal on the Internet (Ramamurthy, et. al., 1992). This information was expanded and made available via a Gopher server, the *UofI Weather Machine,* in January of 1993 (Ramamurthy and Kemp, 1993). Using Gopher client software, any Unix workstation, Macintosh or an IBM-compatible PC on the Internet has a simple, straight-forward way of accessing the *Weather Machine's* products, most of which are updated on a near-real-time basis. The products include surface, upper-air, and operational model forecasts from the National Weather Service, GOES and AVHRR satellite images, severe weather watches and warnings, some climatological data, and other informational documents of interest to the atmospheric sciences community.

The *Weather Machine* has become one of the most highly visible landmarks on the rapidly expanding information super-highway. Time and time again - in newspapers, magazine articles, and other presentations - it has been pointed to as an excellent example of the potential usefulness of the National Information Infrastructure. We have seen a steady increase in the number of requests made to the server. In the past year-and-a-half, server requests have gone from less than 1,000 to an average of over 80,000 per day (Fig. 1). On active weather days, such as during hurricane Emily, the number of calls to this server increased dramatically, exceeding 100,000 daily. The number of organizations connecting to the *Weather Machine* has also grown to include nearly 5,000 different Internet domains, each containing many individual machines. It is being used in research and education. Private citizens, pilots, sailors, skiers, and community centers who have access to the Internet often request information. In addition, the *Weather Machine* is accessed by high schools, community colleges, universities, businesses engaged in computers, networking and publishing, insurance companies, utilities, museums, organizations providing emergency services, media outlets, and several government organizations.

3.0 *The Daily Planet™ from the UofI*
(http://www.atmos.uiuc.edu/)

In March, 1994, the *Weather Machine* Gopher server was extended to a hypermedia environment, which we call *The Daily Planet™*, using Mosaic - a WWW) browser. NCSA Mosaic provides a unified interface to various protocols, data formats, and information archives accessible over the Internet and there are already millions of copies of Mosaic (both public and commercial versions) in use. Currently, *The Daily Planet™* features real-time weather information (including all Weather Machine data), a collection of lists of other weather servers and sources of weather data, local information about the Department of Atmospheric Sciences' faculty and research, plus a growing number of on-line level hypermedia/multimedia instructional modules. The real-time weather information includes over 200 current maps and images, over 1,100 archived images, and 52 MPEG (Moving Pictures Experts Group that generates standards for digital video and audio compression) animations, many of which are updated hourly. Further, TDP is used to post important information relevant to the atmospheric sciences community. Examples include a link to the NASA maintained Mosaic page describing the status of the GOES-8 deployment and a feature on the GLOBE Project, recently announced by Vice-President Gore. The latter includes a 3 minute video/audio clip of an interview with the Vice-President that was made available within hours of Gore's appearance on ABC's Good Morning America program.

Mosaic is an Internet-based graphical global hypermedia browser that allows the user to discover, retrieve, and display documents and data from all over the Internet. It is part of the WWW project, a distributed hypermedia environment originating at CERN. Global hypermedia means that information located around the world is interconnected in an environment that allows the user to travel through information by clicking on hyperlinks -- terms, icons, or images in documents that point to other related documents. Any hyperlink can point to any document anywhere on the Internet. Mosaic also included forms capability for users to supply information such as that needed in making a database request. Users fill in forms – typing in open fields, clicking on button choices, or choosing a menu item - to build up a complex query, which may then be sent to a database search engine and resolved, with data and other information subsequently sent back to the user. This feature can also be used to supply information to a server collecting data, i.e., a student providing local environmental data to the a Globe Project server. Further information on Mosaic can be found in Schatz and Hardin (1994). Mosaic is licensed software that is provided freely through NCSA. Versions of Mosaic for the Mac, for PC Windows, and for Unix systems can be obtained via anonymous FTP at ftp.ncsa.uiuc.edu under /Web/Mosaic. The Mosaic Demo Page can be accessed from within Mosaic at (http://www.ncsa.uiuc.edu/demoweb/demo.html). Mosaic is also provided commercially by several companies with a variety of enhancements and full support.

Hyperlinked documents in Mosaic are written in HTML, a Hypertext Markup Language. HTML is a subset of SGML (Generalized Markup Language), specialized for simple interactive displays with embedded links. SGML is a specification language for the structure of a document, including headers and references, that has been widely adopted throughout the publishing industry. Information on HTML can be found using Mosaic at the following URL (Universal Resource Locator address): (http://wx.atmos.uiuc.edu/kemp/hotlist.html).

3.1 The Weather World
(http://www.atmos.uiuc.edu/wxworld/html/top.html)

The portion of *The Daily Planet™* that provides current weather data is called Weather World. The WWW server differs from the Gopher server in that it provides up-do-date animations of a variety of images and for a variety of time periods. Current *animation* products for the United States and vicinity include infrared satellite images, visible satellite images, satellite water vapor images, satellite floater sector images, surface and upper air maps weather maps using WXMAP, 6-panel surface weather maps, and 6-panel ETA and NGM surface and upper air forecast maps out to 48 hours.

This is the largest animation-oriented display of weather information on the Internet to our knowledge, with the updating of images and maps totally automated. To accomplish this we designed an integrated processing system called *upro* (a contraction of "unified product update processor") that handles the processing of all Weather World products. Most of the basic image content in Weather World was already being produced for distribution on our Weather Machine gopher server by a collection of scripts and other processes. The job of *upro* is to gather the output of these processes from the gopher server directories and other places and to reprocess them into full sized images, small images (used for icons and samples in the HTML pages), image archives and MPEG animations. The HTML pages that provide access to these products are also considered products because they always contain new information including new images.

Each product is defined in a product description. The product description contains information such as the product's unique name, the type of product (image, MPEG, HTML page), the location of the input data (such as in one of the Weather Machine gopher directories) and other type specific characteristics. For all image types these characteristics include items like output image size, cropping, labeling and even options to add a raised boarder around the edge of a reduced image to use as an icon with a three-dimensional appearance. MPEG and archive type characteristics include number of frames or number of images saved, etc.

HTML products also contain a template for the html page to be produced. This template contains normal HTML plus special layout macros that help to keep the style consistent and to keep references to other products such as images. These references are replaced by the actual URL of the latest instance of a given product. This keeps the HTML menus on the server in synchronization with the products available through them.

There is also the capability to use template products. These template products form a class-like hierarchy that simplifies product definition. All products need not redefine every characteristic. A parent class for that product type can hold default characteristics while the specific product description holds only information unique to that particular product. As many levels can be added to the hierarchy as desired.

Upro keeps all of this information in its internal database and is launched automatically about once an hour. It scans its database and looks for products that need updating. An MPEG satellite loop may need to have a new frame added to it, for example, when a new image has appeared in its input directory (in this case, one of the image directories on the gopher server). The image is processed and added to the animation. If this particular animation is set to hold only the last 24 frames, the oldest frame is removed to make room for the new one. The new MPEG file is then placed in one of the TDP server's directories. The HTML page that references it is also updated to reflect the newly updated animation. This sequence is repeated in a similar manner for all other products.

Nearly all of our weather data files (before and after processing) have the time and date encoded into the filename. *Upro* can interpret this (via a filename format specification in the product description) and use this information to better track the files and organize them properly.

Because it maintains information in its database about the contents of both input and output directories as well as the products, *upro* can detect changes in any of these places and respond accordingly. It can take note of new files in input directories and sense the removal of files in output directories. For example, if one were to start randomly deleting files from the WWW server directories, these files would automatically be replaced during the next *upro* run. With the product definitions safely backed up, the system is fully self-recoverable from major problems. In fact, we've purposely deleted the entire server directory structure in rare instances to force a complete rebuild.

Efficiency is of major concern. If there are products that need to be updated every hour and it takes more than an hour to process them all, the server would certainly not be able to keep up with incoming data. One of our approaches has been to distribute the load (by task) across multiple machines. Input data is generated and stored on two machines, while output data is served to the WWW on a third machine. A fourth machine sits in the middle of the chain running *upro*. The other approach has been to develop special software to increase the efficiency of certain computationally intensive tasks such as MPEG production in particular. At present it takes approximately 45 minutes to process each hour's worth of data on the machine running *upro*.

A future version will be more comprehensive and use a more sophisticated database, possibly even to store the image and animation data itself.

3.2 Multimedia Modules Available in *The Daily Planet™*

(http://www.atmos.uiuc.edu/covis/modules/html/module.html)

Internet-accessible multimedia instructional modules that introduce and explain a variety of important concepts in atmospheric sciences are available in *The Daily Planet™*. They consist of text, colorful diagrams, animations and movies, audio, and scanned images, that introduce and explain a variety of important concepts in atmospheric sciences. These multimedia instructional modules are being developed for use at the high school level, but are also useful for general undergraduate education (Ramamurthy and Wilhelmson, 1993; Ramamurthy et al., 1994). The modules are being tested at the two current CoVis schools in the Chicago area, and they are being revised and refined based on the feedback from them (Ramamurthy et al., 1995). Such multimedia-based instruction provides an alternative approach to learning, one in which the student, through interaction with the computer, becomes actively involved in the learning process that includes current weather data.

The Pressure and the Forces and Wind modules include descriptions of high and low pressure centers and the balance of forces that generate winds. These are enhanced through the use of colorful diagrams and animations, video clips, and audio narration. A module entitled Guide to Weather Maps and Images provides important information on understanding many of the weather displays available in TDP. We have also developed a hypermedia Glossary for the modules that have been developed thus far. Other modules currently under development include: (1) Cloud Catalog, (2) Guide to Atmospheric Optics, (3) Tornado Spotters Guide, and (4) Severe Storms Guide. The ultimate goal is to deliver an entire multimedia textbook over the Internet for use by students and the general public.

4.0 Future Development

The growth in data available over the Internet has been astronomical and with the availability of data through such programs as EOS will continue to grow. It is vital that appropriate information be locatable by an interested researcher, educator, or the general public. For the most part, data archives and digital libraries in earth sciences have been generally established to aid scientists in carrying out research. Typically, scientists know a lot about the type of data they are studying or

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have the ability to find what they need to know. Further, they generally have the skills to deal with different data formats, user interfaces, and query requirements, and they have considerable computer resources available to handle the massive volumes of data which might have to be filtered in order to obtain the desired data. However, even they will have difficulty locating useful information within the growing number of Internet data servers. Mosaic development and digital library research is currently underway at the University of Illinois to address these needs.

Recently, support from NASA has been obtained to test applications and digital library technologies in Support of Public Access to Earth and Space Science Data. This joint work involves the Department of Atmospheric Sciences, NCSA, and the Computer Science Department faculty and staff at the University of Illinois. Data from the earth and space science community (including supplementary information and education modules) will be utilized to test server technologies needed to support effective access to the data and information. These technologies will address the issue of scalability needed to deal with the growth in available data. In the data management area, the focus is on integrating data from different sources without undergoing costly data conversion and the need for rapid access to parts of very large data sets. For information technologies, work is being undertaken to provide the users with the server-side tools needed to find the information they desire, to interact with it, and to analyze it. The scalable server technologies merges the other technology areas, addressing problems of dealing with large and numerous files on web servers along with tertiary storage issues related to these files. In addition, client software development, the only component directly seen by the user, will include Mosaic enhancements and associated software development needed to improve the use of images in providing hyperlinks and hypermedia and in overlaying and subsetting of data and images.

The Daily Planet™ will serve as the major initial testbed of the new software developed. A prototype interface, designed in Mosaic, will allow users to browse the available metadata and select subsets of this data to be delivered in either HDF or netCDF formats for downloading. The available data would initially include GOES and AVHRR processed and value-added data and images. The amount of data available from on-line will be significantly increased in order to assess scalability and tertiary storage technology developments. This will be accomplished using the above data together with additional datasets (specifically DMSP or SMM/I data and UARS).

The Daily Planet™ will also incorporate software developed to allow the comparison or overlaying of data in order to examine relationships. An example would be to overlay AVHRR derived vegetation data with SSM/I derived precipitation data to note the relationship between rainfall amount and vegetation cover or to overlay GOES water vapor data with precipitation to note their relationship. A Mosaic-based interface that extends the data browse and subsetting features would allow selections from different datasets to be compared. New Mosaic features such as the extended GIS (Geographical Information System) hypermedia interface would also be incorporated in *The Daily Planet™*.

Finally, through other funding and collaborations, new multimedia modules, new weather products, and additional climate data will be added to *The Daily Planet™* . This will include data from the Midwest Climate Center and other midwest hydrologic data, as well as flood and water quality information. *The Daily Planet™* will be adapted to include environmental data collected in the Globe Project and adaptations will be made to maximize its usefulness in K-12 education in both the urban and rural settings and to improve scientific literacy both nationally and internationally.

5.0 Acknowledgments

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J6.7 COMET®: A PROGRAM UPDATE AND LOOK TO THE FUTURE

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1. BACKGROUND

During the 1980s, the National Weather Service (NWS) embarked on a major modernization program that includes the installation of state-of-the-art observing systems and extensive reorganization of the NWS' field office structure. As part of this effort, a strong emphasis has been placed on enhancing the professional background and capabilities of operational meteorologists and hydrologists to use mesoscale information. Additionally, the NWS recognized the need to accelerate the transfer of information from research activities into practical operations. Three means by which these goals could be accomplished were identified: 1) intensive and ongoing education and training for meteorologists now employed; 2) increased collaboration between the operational and research communities; and 3) improvements to university education throughout the country in order to provide future meteorologists with stronger educational and professional qualifications.

At the request of the NWS, the University Corporation for Atmospheric Research (UCAR) established the *Cooperative Program for Operational Meteorology, Education and Training* (COMET) with the following objectives:

1) Support the professional development of weather forecasters and hydrologists through a program of in-residence interactions with research scientists and the creation of an effective means of delivering such knowledge remotely to both students and operational forecasters;
2) Facilitate the transfer of research results to operational forecasting through the development and testing of forecasting techniques;
3) Provide a mechanism for the participation of operational forecasters, research scientists, and academic scholars in advancing the weather services of the nation;
4) Stimulate the further advancement of basic and applied research in the science of forecasting and nowcasting techniques.

The three COMET programs that have been developed to meet these objectives are the Residence Program, the Distance Learning Program, and the Outreach Program. These three programs are described in the following sections. COMET is also reviewing ways in which it can broaden its scope of activities in areas consistent with the general UCAR objectives related to education and technology transfer. A vision for what these activities might include is described in Section 3.

2. CURRENT COMET PROGRAMS

2.1 *The Residence Program*

The Residence Program was created to develop and offer courses, symposia, and workshops that provide operational weather forecasters, hydrologists, and other atmospheric scientists with new skills and concepts in mesoscale meteorology. Classes offered through the Residence Program are conducted by both academic and operationally experienced instructors, using a case study approach to teach advanced-level topics. The program is dedicated to bringing meteorologists and hydrologists with specialized duties together with nationally recognized experts for the purpose of improving their collective understanding of mesoscale meteorology.

The cornerstone of the Residence Program is a classroom that currently relies on personal computer (PC) workstations. The classroom, located at the UCAR Foothills Laboratory in Boulder, is approximately 2000 square feet in size and has classroom seating in the front of the facility for 24 students and visitors. Nine workstations (for a class of 18 students) are located in the rear of the classroom.

An extensive library of mesoscale case studies of integrated surface, upper air, satellite, and radar data has been developed by COMET staff for use in both the Residence Program and the Distance Learning Program. A typical Residence Program course uses up to 16 case studies to support lecture topics and displaced real-time (DRT) laboratory exercises. DRT exercises contain data

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that have been previously collected and integrated in a format that allows the student to review essentially the same products that a forecaster would see in real time. As interesting weather events occur, new case studies are created using COMET-developed software that can process operational data, as well as experimental data such as field study observations. Real-time data displayed with Forecast Systems Laboratory software, GEMPAK, and the PC Gridded Information Display and Diagnosis System are used to support weather briefings and other class discussions during significant weather events.

The main focus of the Residence Program during the last few years has been to offer the following courses:

COMAP Course: The COMET Mesoscale Analysis and Prediction Course (COMAP) provides an in-depth review of mesoscale meteorology and is designed specifically for the science and operations officer (SOO) at each NWS Weather Service Forecast Office. The SOO at each field office serves as the scientific leader and coordinates research projects between the office and academic/research institutions. COMAP, an eight-week course, is taught at the graduate level, and includes case studies to illustrate mesoscale phenomena, DRT case studies to simulate the forecasting environment, seminars by visiting scientists, discussions of new observing systems, and supervised interactions with local Boulder scientists on independent research projects.

Annual Mesoscale Course: This course provides an overview of mesoscale meteorology and lasts three weeks. Taught at the graduate level, the Mesoscale Course uses many of the same materials as the COMAP Course and also provides the students with opportunities to utilize COMET computer-based learning modules. The course is offered to regional headquarters and national center meteorologists within the NWS, U.S. Department of Defense, private sector, and foreign governments.

Hydrometeorology Course: This course is a three-week overview of hydrometeorology and meteorological events producing both flash and systemic flooding. The course is designed for service hydrologists, hydrometeorological analysis and support forecasters, hydrology focal points, and other hydrologists. The principle objective is to increase the participants' knowledge of the interaction between hydrology and meteorology during flood events and to improve their knowledge of new hydrometeorological observing systems.

Faculty Course: The Faculty Course is a two-week course in mesoscale meteorology designed for university faculty who wish to offer a new course in mesoscale meteorology or improve a course that is already being taught.

Manager's Course: The Manager's Course is a one-week mesoscale meteorology course designed for government and private sector managers. The course demonstrates the new opportunities that now exist for improving short-range forecasts of significant weather through the use of new observing systems.

Residence Program activities planned for the next five years will focus primarily on the presentation of the core courses. Table 1 lists the number of weeks the various courses will be taught each year through 1997. Starting in 1996, a two-week course on GOES satellite interpretation will be taught twice per year. The course will be designed for satellite focal points and other individuals who will lead on-station training. In addition, COMAP follow-on symposia will be offered two or three times a year beginning in 1995. These one-week symposia will cover recent advances in mesoscale research and will provide a mechanism for the exchange of training and forecast technique development ideas.

2.2 *The Distance Learning Program*

Cost and staffing limitations make it impossible for the nation's forecasters to meet their education needs entirely through the Residence Program at COMET or through similar on-site courses and workshops. The COMET Distance Learning Program was established in response to this need for professional development opportunities in the field office. The objective of the program is to provide education for operational weather forecasters, university faculty and students, and other meteorologists in the techniques of modern weather forecasting, including the use of new observational tools. Efforts to date have focused almost entirely on developing interactive, multimedia computer-based learning (CBL) instructional materials.

A CBL system consists of an interactive software module that teaches a specific topic and the computer hardware required to run the module. A typical CBL module contains four to eight hours of highly interactive instruction and utilizes a mixture of case studies, graphics, animation, and video to provide an effective educational experience. Concepts are introduced via both computer text and spoken dialogue and are reinforced by displays of such graphic materials as time-sequenced satellite and radar data and videos demonstrating laboratory experiments or showing experts explaining concepts. At various points throughout each module, the student has the opportunity to practice using concepts covered in the module by answering questions and/or working through sample case studies. If the student would like more detailed information during the process or provides an incorrect response to a question, additional material is presented, often by an expert in the particular field.

The development of a CBL module is a complex process, requiring the interaction of instructional designers, meteorologists, hydrologists, graphics and media specialists, computer scientists, and other experts in the specific field addressed by each module. Eight modules have already been produced, and over 20 additional modules will be developed during the next six years. All of the COMET modules will form an operational forecaster's multimedia library covering important aspects of operational forecasting and emphasizing mesoscale meteorology. Published modules (as of the end of 1994) include the following:

Workshop on Doppler Radar Interpretation: Three learning methods are highlighted in this module: basic interpretation of patterns associated with fronts, convergence and divergence, etc.; integration of other meteorological information with radar data; and compensation for complications in radar data, such as range folding and aliasing. Content experts are Donald Burgess of the NWS Weather Surveillance Radar - Doppler (WSR-88D) Operational Support Facility and Larry Dunn of the NWS Salt Lake City Forecast Office.

Boundary Detection and Convection Initiation: This module focuses on challenges frequently faced by forecasters in an operational environment. It teaches how to detect, using a variety of observational data, important convergence boundaries embedded in the boundary layer and how to make short-range forecasts (0-1 h) using several forecast guidelines. James Wilson of NCAR and James Purdom of the National Environmental Satellite Data and Information Service (NESDIS) are the content experts.

Heavy Precipitation and Flash Flooding: This module provides an introductory-level understanding of the multiple factors and conditions that go into a forecast of the potential for flash flooding. Subject matter experts outline important flash flood forecasting and monitoring methodologies through step-by-step observation and analysis demonstrations. Content experts are Charles Chappell of COMET, Rod Scofield of NESDIS, and Tim Sweeney of the NWS Office of Hydrology.

Forecast Process: The modernization of sensing and data acquisition systems makes it even more critical that forecasters have a consistent general framework for properly observing, organizing, analyzing, diagnosing, and forecasting meteorological conditions and events using this increasing supply of new data. The focus of this module is on developing and applying such a systematic approach to operational forecasting. Len Snellman, a retired NWS Scientific Services Division chief, and Eric Thaler, the SOO at the NWS Denver Forecast Office, served as content experts.

Marine Meteorology Volume I: In this module, through a unique set of interviews with mariners involved in a variety of activities ranging from military operations to recreational uses, the learner gains an understanding of the need for accurate marine forecasts. The module also provides a basic understanding of wave and swell dynamics and forecasting. Both deep water wave development and shallow water wave interactions are presented through a simple set of wave equations and graphics. The concepts of fetch length, wind duration, and wind speed are used in a wave nomogram to forecast wave generation. A case study demonstrating a technique for forecasting the arrival time and height of swell at a coastal location is presented by one of the content experts, Steve Lyons, of the National Hurricane Center. The two other content experts are Carlyle Wash of the Naval Postgraduate School and Steve Reinard of the NWS Southern Region Headquarters.

Marine Meteorology Volume II: Forecasting in the marine environment requires an understanding of the differences in the characteristics of the planetary boundary layer between the ocean and land. This module is an extension of volume I and concentrates on stability and surface roughness influences with respect to forecasting surface winds over open water. Use of a wind nomogram and the geostrophic wind relationship are presented to develop surface wind forecasts. The forecast of surface wind speed is then applied to wave height and period forecasting through use of the wave nomogram. A case study engages the learner in an exercise where the surface wind speed, fetch length and duration must all be determined before providing a wave height and period forecast for three different locations within the Gulf of Mexico. The content experts for this module are Steve Lyons of the National Hurricane Center, Carlyle Wash of the Naval Postgraduate School, and Steve Reinard of the NWS Southern Region Headquarters.

Extratropical Cyclones Volume I: Several of the primary conceptual topics and forecasting methods related to extratropical cyclogenesis and evolution are presented in this module. The relationships between upper-level jet streaks, conveyor belts, heat and moisture are discussed with regard to their role in the development and evolution of extratropical cyclones. The analysis of ageostrophic motions, potential vorticity, Q vectors, and the assessment of numerical model forecasts are presented to aid the learner in diagnosing and forecasting these storm systems. A case study engages the learner in applying these techniques to forecasting the evolution of a frontal wave cyclone and its attendant weather at several locations. The content experts for this module are John Nielsen-Gammon of the Department of Meteorology at Texas A&M University, and Roger Weldon of NESDIS, Satellite Applications Division.

Numerical Weather Prediction: In the COMET course on Numerical Weather Prediction (NWP), each component of an NWP system is analyzed in terms of the processes that define it. An in-depth explanation of the principles and practices of NWP data collection, quality control, analysis, forecast modeling, post-processing and verification lead to a thorough understanding of the strengths and weaknesses of NWP. Through the NWP module, a forecaster is given the means to assess the appropriateness of applying any particular NWP system to a given forecast problem. From this knowledge it is possible to evaluate the validity of the guidance. The forecaster is then able to make critical subjective adjustments to NWP guidance based upon new insights into NWP and meteorological principles. The module also includes an analysis of sources of possible NWP forecast error, and two case studies that explore the effectiveness of NWP model runs for particular weather situations. Fred Carr of the University of Oklahoma, School of Meteorology, and Ralph Petersen, of the NWS Office of Meteorology, are the content experts.

Hydrology for the Meteorologist: In this module basic concepts of hydrology are taught through the application of preparing a river forecast. The module presents a review of current hydrologic forecasting tools, as well as an introduction to future computerized tools. The content experts for this module are Gerald Nibler of the Alaska River Forecast Center and C. Mike Callahan of the NWS Forecast Office in Louisville, KY.

Currently, COMET modules are published with the video portions on the laser disks. We are actively working to transition by 1996 to digital video publication which will allow COMET modules to be played on inexpensive multimedia personal computers.

2.3. *The Outreach Program*

The Residence and Distance Learning Programs were created to address the objectives of improving the education of operational forecasters and meteorology students. The Outreach Program is an important element of the COMET program in that it meets a different COMET objective–that of advancing applied research in mesoscale meteorology. In the past, operational weather services and academic researchers have not often communicated effectively. As a result, operational weather forecasters have sometimes been unaware of recent advances in meteorological research, while meteorological research conducted in universities has tended to focus more on basic research than on issues of foremost concern to operational weather forecasters. The Outreach Program is designed to address this communication problem by creating partnerships between members of the academic research and operational forecasting communities that will facilitate the flow of ideas and concepts to the benefit of both groups.

Under the Outreach Program, COMET provides modest financial support for these partnerships in three areas: NWS Cooperative Projects, NWS Partners Projects, and Air Weather Service (AWS) Projects.

Cooperative Projects: Cooperative Projects typically involve broad interactions between a university meteorology program and a local NWS office. These projects undergo a competitive selection process and an annual review. Funding is usually for a two- or three-year period at an average level of $20,000 - $25,000 per year.

Partners Projects: Partners Projects involve a single university professor or laboratory researcher who collaborates with a forecaster on a specific problem of mutual interest. These are generally one-year research studies that are funded at a level of approximately $5,000, subject to a favorable review and available funding.

AWS Projects: In 1992, the AWS began sponsorship of the Outreach Program when its first project was funded. The two AWS Outreach Projects funded thus far have been similar to Cooperative Projects in level of funding and duration.

During 1994, 14 new Cooperative Projects, 2 AWS projects, and 15 Partners Projects received funding. Outreach Program efforts are described in an annual report that summarizes the research results from Outreach Projects. Table 2 lists some of the projects currently being supported.

The Outreach Program is continuing to expand in terms of the number of projects funded and total funds available. Although the support provided to each project is relatively modest, the program has proven to be highly successful in promoting educational and research exchanges between academic researchers and operational forecasters, many of whom conduct part of the research on their own time. By 1996, it is expected that the number of projects funded by both the AWS and the NWS will increase.

Future plans for the Outreach Program include organizing workshops that will address recent advances in mesoscale meteorology unique to various regions. One such workshop will occur in 1995 and will bring together tropical meteorologists in Hawaii to discuss how new observing systems can be used to improve weather forecasting in the Pacific region. Special two- or three-week mesoscale meteorology workshops for government, academic, and private sector forecasters will also be offered in the future.

3. THE FUTURE OF COMET

Of the many possible activities COMET could pursue in the next five years, not all meet the original goals of the program. The first priority is, of course, to meet these objectives as stated in the agreement between UCAR and the National Oceanic and Atmospheric Administration (NOAA). However, COMET is frequently contacted by other governmental agencies, educational institutions, and foreign governments that are interested in making use of their services. The kind of support COMET can give these organizations is currently governed by the availability of resources for taking on additional projects, as well as by how well the request fits with the basic COMET mission and UCAR's goals and objectives. Available resources will be very limited in the next few years, however, given the intensive Residence Program schedule and the CBL module production schedules. In future years, when the core objectives have been largely met or have diminished somewhat, COMET may well be ready to take on additional activities. Those chosen will likely be ones that promote improved forecasting techniques and/or education in the field of meteorology and, consequently, fit best within a broad definition of the COMET program. Some of the activities that COMET may undertake in the future include:

- A pilot program in the use of videoconferencing;
- Development of a performance support system to provide critical information at the time of need on operational workstations;
- Development of an on-line reference system for integration into meteorological workstations;
- Support for regional information exchanges and workshops on new mesoscale research and data findings;
- Development of CBL modules for other populations, including weather broadcasters, private sector meteorologists, and pilots;
- Promotion of improved weather forecasts in other countries by offering courses in modern weather forecasting, developing CBL modules for operational forecasters of other nations, and translating existing CBL modules into other languages;
- Assistance in the development of university correspondence courses in meteorology that make use of COMET CBL materials;
- Improvements to the education of the next generation of operational forecasters by offering courses and workshops in modern mesoscale analysis and prediction to professors of synoptic and mesoscale meteorology and assisting meteorology departments in the integration of multimedia learning techniques into their curriculum.

4. CONCLUSIONS

As the nation enters a new era in forecasting capabilities, the importance of having an educated and well-trained professional hydrometeorological work force cannot be overestimated. Similarly, the need for collaboration between the operational forecasting community and the research community has never been greater. The COMET program is a key component in meeting these needs and will likely continue to play a major role in improving mesoscale meteorology education in this country and throughout the world.

5. ACKNOWLEDGEMENTS

This paper is funded by a cooperative agreement from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the author (s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

Table 1: Number of weeks of teaching in each year

	1991/1992	1993	1994	1995	1996	1997	Total
COMAP	8	8	16	16	16	16	80
HYDROMET	0	6	9	9	9	6	39
Follow-on symposium	0	0	0	2	4	4	10
Mesoscale Meteorology	3	3	3	3	3	3	18
Manager's course	0	0	2	2	2	2	8
Faculty course	0	0	2	0	2	0	4
Faculty workshop	0	0	1	0	1	0	2
Regional workshop*	0	0	0	2	6	10	18
Courses for foreign govts	3	0	0	0	0	0	3
GOES	0	0	0	0	6	6	12
Total	14	17	33	34	49	47	194

*Off-site

Table 2: Example Research Topics Supported by the COMET Outreach Program in 1994

UNIVERSITY	FORECAST OFFICE	TOPIC
Univ. of California (San Diego)	NWS Alaska Region	Integration of Optical Line Scanner (OLS) and Special Sensor Microwave Imager (SSM/I) data into operational weather forecasting.
Univ. of Hawaii	NWS Honolulu	Regional environmental analysis project for the Pacific.
Iowa State University	NWS Chicago, Minneapolis, Des Moines	Forecasting nocturnal mesoscale convection.
Univ. of Oklahoma	NWS Norman, Arkansas-Red Basin RFC	Improving estimates of surface rainfall and river stage forecasts.
Univ. of Virginia	NWS Pittsburgh, RFC Cincinnati	Probabilistic river stage forecasting.
Colorado State Univ.	NWS Phoenix	NEXRAD and lightning studies.
Univ. of South Carolina	NWS Columbia	Use of prototype GIS to integrate topographic, hydrologic, and climatic data with WSR-88D data.
North Carolina State Univ	AWS/Cape Kennedy	Nowcasting convective activity during space shuttle launches and landing.

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AN UPDATE ON NCDC'S CD-ROM PRODUCTS AND ON-LINE SERVICES AVAILABLE FOR EDUCATORS.

Thomas F. Ross

National Climatic Data Center
Asheville, North Carolina

1. INTRODUCTION

The National Climatic Data Center (NCDC) is part of the National Oceanic and Atmospheric Administration (NOAA), which is under the umbrella of the Department of Commerce (DOC). NCDC's mission is to manage and disseminate national and global environmental data. As operator of the World Data Center-A for Meteorology, which promotes international data exchange, NCDC collects data from around the globe. NCDC performs different data management techniques depending on data type archived. NCDC archives nearly a quarter-million magnetic tapes/cartridges, 1.2 million microfiche records, and 319 million paper records. NCDC has more than 150 years of data on hand and adds 55 gigabytes of new information each day.

One of the major efforts in data management at NCDC is the development of CD-ROM products using NCDC's digital database. NCDC has produced a suite of CD-ROM products ranging from hourly U.S. observational data, gridded global monthly upper air analysis, to tropical storm plots worldwide.

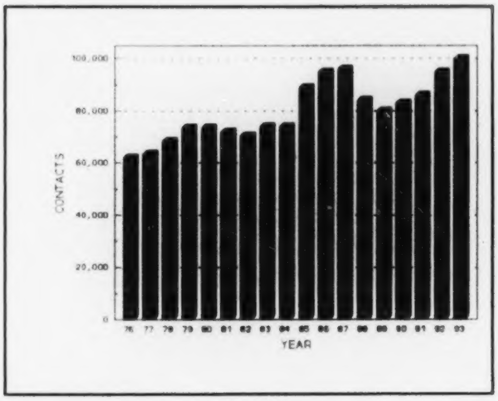
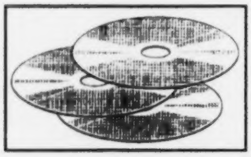


Fig 1. NCDC Yearly Contacts.

NCDC averages over 9,000 user contacts per month concerning data availability. Requests from educators and university researchers make up 2 to 5 % of that total or about 200-400 requests per month. The majority of requests are handled by telephone, electronic mail, letter, or fax. The yearly number of contacts is shown in Figure 1. NCDC contacts include a wide spectrum of users in the business, academic and government fields. Major user groups include: consultants, business, legal, engineering, government, researchers, and education. Users have different capabilities for receiving and using climatological data. Researchers may have access to Internet, whereas the legal community requires paper copy records. NCDC's commitment to data dissemination spans all these users. New CD-ROM products developed by NCDC can be useful classroom tools to teach meteorology, climatology or even basic geography in an interactive way. Students can select and define geographic regions and climatic variables using the CD-ROM display, and then print or capture the data to a file and even graph selected products.

2. CD-ROM PRODUCTS



--International Station Meteorological Climate Summary (ISMCS) Ver 3.0. This product has detailed climatological summaries for 2200 worldwide locations. They include National Weather Service offices, domestic and overseas Navy and Air Force sites, and selected foreign stations. Limited summaries are included for almost an additional 5,000 worldwide sites. Tabular or statistical data can be exported to a printer, spreadsheet. Version 3.0 supports mouse capability and graphics. Joint NCDC, USAF, and U.S. Navy product.

--National Climate Information Disc Vol 1.0. This CD-ROM contains monthly sequential temperature, precipitation, and drought data for 344 climate divisions in the contiguous U.S. The data can be viewed in a tabular or graphical format and output sent to a printer. The CD-ROM covers the period 1895-1989 and contains 1032 time-series graphs, 4180 maps, and 5400 frames of video animation. NCDC product.

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-- **U.S. Navy Marine Climatic Atlas of the World - Ver 2.0.** This CD-ROM includes analysis and display software for climatological averages of atmospheric and oceanographic data. The data are summarized with user-defined 1 and 5 degree grid areas covering the global marine environment. The summaries are produced using predominantly ship data collected between 1854-1969. The major elements include air and sea temperature, dewpoint temperature, scalar wind speed, sea-level pressure, wave height, wind and ocean-current roses. This product allows users to define element intervals (e.g. 5 to 10 knots, 2 degree temperature intervals). Contouring for explicitly user-defined regions and exporting data to a printer or diskette are supported. Ocean basin narratives and Mediterranean port guides were added in this version. U.S. Navy sponsored product.

--**Global Upper Air Climatic Atlas (GUACA).** This two-volume CD-ROM set uses 12-year (1980-1991) 2.5 degree gridded upper air climatic summaries derived from the European Centre for Medium Range Weather Forecasts (ECMWF) model analyses. This product presents monthly upper air statistics for 15 different vertical levels in the Northern and Southern Hemisphere for dry bulb and dewpoint temperature, geopotential height, air density, and vector and scalar wind speed. Access/display software for gridpoint data, contouring capability for user-defined areas, and vertical profiles are also supported. The climatology covers the 12-year period as well as individual year-months. Joint NCDC and U.S. Navy product.

-- **CLIVUE CD-ROM.** The National Climatic Data Center (NCDC) developed a CD-ROM in support of a museum exhibit which traveled across the U.S. The CD-ROM contains a 1,500-station subset of NCDC's nearly 8,000 U.S. daily cooperative stations. The user selects a date and area of the U.S. and the CD-ROM database is queried for stations within the specified domain having data. Then, the system displays daily maximum and minimum temperatures, precipitation, and snowfall for the site. Graphs showing 7 years, 21 years, and the full period of record (varies by station) for the station(s) are available. Visual displays allow users to view trends, variability, and extremes. Joint NCDC and Franklin Institute product.

-- **SAMSON CD-ROM Set.** NCDC developed a Solar and Meteorological Surface Observational Network (SAMSON) three-volume CD-ROM set. The three CD-ROMs are divided geographically into regions: eastern, central, and western U.S., and contain hourly solar radiation data along with selected meteorological elements for the period 1961-1990. It encompasses 237 NWS stations in the United States, plus offices in Guam and Puerto Rico. The dataset includes both observational and modeled data. The hourly solar elements are:
Extraterrestrial horizontal and extraterrestrial direct normal radiation; global, diffuse, and direct normal radiation. Meteorological elements are: Total and opaque sky cover, temperature and dew point, relative humidity, pressure, wind direction and speed, visibility, ceiling height, present weather, precipitable water, aerosol optical depth, snow depth, days since last snowfall, and hourly precipitation. Joint NCDC and NREL product.

--**Radiosonde Data of North America 1946-1993.** Contains all available radiosonde data for North America (U.S., Canada, Mexico, and Caribbean Islands) through the 100-mb level on four disks. Disk periods are 1946-1965, 1966-1979, 1980-1989, and 1990-1993. Data includes significant, mandatory, and special wind levels for all observation times and includes geopotential height, temperature, dew point, wind direction, and scalar speed. The user can select for output to printer, screen, or file: A single station or multiple stations for a defined time period, or all stations within a specified geographic region in either synoptic or station sort. The CD-ROM also contains available station metadata. Joint NCDC and ERL product, available as 4 volume set only.

-- **Global Tropical and Extratropical Cyclone Climatic Atlas (GTECCA) Ver 2.0.** This single volume CD-ROM contains global historic tropical storm track data available for five tropical storm basins. Periods of record varies for each basin, with the beginning as early as the 1870s and 1993 as the latest year. Northern hemispheric extratropical storm track data will be included from 1965 to 1993. Tropical track data includes time, position, storm stage (and maximum wind, central pressure when available). The user has the option to display tracks, and track data for any basin or user-selected geographic area. The user can select storm tracks passing within a user-defined radius of any point. Narratives for all tropical storms (varying periods by basin) are included as well as basin-wide tropical storm climatology. Requires 520K of RAM memory. Joint NCDC and U.S. Navy product.

-- **Global Daily Summary (GDS).** This CD-ROM provides access to a 10,000-worldwide station set of daily maximum/minimum temperature, daily precipitation, and 3-hourly present weather for the 1977-1991 period of record. Data can be selected for viewing or output to file for geographic areas or by a predefined user-selected list of stations. The dataset includes element flags for suspected erroneous data. A data inventory contains station name, latitude and longitude, elevation, period of record, and the number of observations of available data. Requires a bare minimum of 4 MB of RAM with 8 MB of RAM recommended for superior performance.

-- **Station Climatic Daily Summary Ver 1.0.** Summary statistics and access software provided to present daily data for over 500 major NWS , U.S. Navy and USAF stations worldwide. This CD-ROM provides menu driven software utilities which allow multiple type queries to the database. Frequency distributions, bivariate distributions are included. The general Period of Record (POR) is 1948-1993 but is longer for some stations. Joint NCDC , U.S. Navy and USAF product.

-- **Hourly Modeled Sounding Data.** This 12 volume CD-ROM set contains hourly 60 KM gridpoint U.S. sounding data for 1990. This data is the output from the Penn State University MM4 model which used available daily sounding data for 1990 as input. One of the applications of this CD-ROM is to access air pollution impacts on a local scale. Joint NCDC and ARL product.

-- **NCDC Cooperative Station Data.** This 19 volume CD-ROM set has TD-3200 Cooperative station data. Major elements include daily high and low temperatures, daily rainfall, daily snowfall and snow depth and evaporation. General POR is 1948-1993 but is longer for selected stations. This version will contain inventories, station history, and raw data, but no access display software. Joint NCDC and ARL project.

-- **Global Historic Fields.** This CD allows users to view daily surface charts for the period 1899 through April 1994. Daily upper air charts (700 mb, 500 mb, 300 mb) are available from the 1940's through April 1994. Charts have pressure fields contoured, and can be exported to a file or printer. Joint NCDC and U.S. Navy product.

-- **Climatic Data and Summaries for Buoys and C-MAN Stations.** This CD-ROM presents statistical summaries and hourly data for NDBC moored buoys and coastal marine (C-MAN) stations. Period of record will vary by site depending on data availability. Joint NCDC and NDBC product.

3. ON-LINE DATA ACCESS

a. NCDC On-Line Access and Service Information System (OASIS)

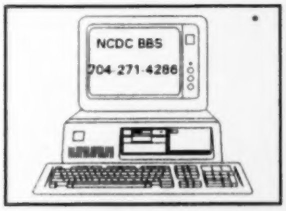
NCDC has on-line data and metadata available by FTP computer access. Data are placed on-line as soon as possible after receipt and processing. These data are available without charge via FTP for immediate downloading (up to 50MB), or users can order data for off-line delivery (standard NCDC charges). OASIS datasets include Wind Profiler, Surface Hourly and Upper Air Data, Cooperative Summary of the Day, Climate Division data, Hourly and 15-Minute Precipitation data, and General Circulation Model data. Most datasets are available from NCDC in either enhanced BUFR or ASCII format. Details about formats and format translators are available on-line. In addition to data, important metadata are included with the on-line data. Station histories, data dictionaries, field experiment information, and data inventories are available.

Access to the system is via Internet using telnet. Please use the address 192.67.134.72 or hurricane.ncdc.noaa.gov

The Login is :	storm
The Password is :	research

b. Bulletin Board Access at NCDC.

The National Climatic Data Center (NCDC) Bulletin Board System (BBS) is a PC-based system with 400 mb of data storage. The bulletin board operates 24 hours/day using PC Board software for its primary operating system, and can be accessed using most commercial modems. Simply follow the instructions given after dialing into the system.



Modem Specifications for Accessing BBS

Telephone:	(704) 271-4286
Baud rate:	1200, 2400, 4800, or 9600
Parity:	No
Data bits:	8
Stop bits:	1
Echo:	Y or N

(Please call 704-271-4619 if you have technical questions.)

NCDC Bulletin Board Products

There are several different products available on the Bulletin Board, each having unique file name(s). Product documentation is available for several of the data files listed below. This documentation provides formats and further interpretation and clarification of the data. Without using these files, the data are often difficult or impossible to understand. A separate file has been developed for selected products. It is suggested that you download and print the documentation file for each product you will be using and save for future use. The same format will be used for all files with the same product name.

--Preliminary Monthly Summary
--Printable Local Climatological Data
--Spreadsheet Local Climatological Data
--Station Narratives
--Printable ASOS Local Climatological Data
--ASOS Unedited Summary of the Day NWS F6
--Daily Weather Highlights
--Major Weather Events
--Other Data and Services

Selected Products on NCDC BBS

A complete BBS users manual with details and subscription information is available from NCDC.

c. NCDC Home Page Via the World Wide Web

NCDC has developed a Home Page accessible via the World Wide Web (WWW) using Mosaic. The NCDC Home page, with information about products and services, can be accessed at the following WWW address:

http://www.ncdc.noaa.gov

A wealth of information and data are available via the NCDC Home Page. Sample products range from NCDC technical reports, LCD annual summaries, inventories, global summary of the day, and Interactive On-Line Climatological Products.
! Explore the System !

d. NCDC FTP Access

Newly evolving computer technology has allowed the NCDC to offer anonymous FTP via Internet as a data transfer mechanism.

e. NCDC FTP Inventory Access

The following are instructions for obtaining certain data inventories via internet from NCDC. An NCDC workstation has a subdirectory called "inventories" where the inventory files are located. User's should login to the workstation using internet via FTP. Please enter commands in lower case letters. These files are also available through our mosaic/homepage server at -- http://www.ncdc.noaa.gov

a) Enter: open 192.67.134.72 or
open hurricane.ncdc.noaa.gov

b) Login is: anonymous

c) Password is: your email address

d) You are now logged onto a UNIX workstation. Enter "help" if you'd like a list of available commands.

e) To move to the correct subdirectory, enter:
cd /pub/data/inventories

f) To get a copy of the file descriptions, enter:
get README.TXT destination (destination is your output location and name)...e.g.--
get README.TXT c:README.TXT - copies to hard drive c:
Note that file names are in all CAPITAL letters.

g) Then, to get a copy of any of the inventory files, use the same procedure.

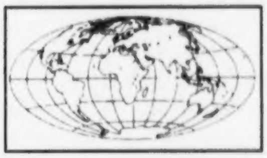
h) To logoff the system when finished, enter:
bye

The "README.TXT" file describes the various inventory information that is available. The inventory files cover many of NCDC's most popular databases and products.

Notes: All files are ASCII text format with a "TXT" name extension (e.g., COOP.TXT). File names are strictly upper-case. The files will be updated periodically as soon as resources/information allow. To read any of the files, you can use Wordperfect or any other editor. In Wordperfect, the "TEXT IN" command (CTRL-F5) will read in a large file rather quickly, and the "SEARCH" command (F2) will locate a character string (e.g., a station name). Of course, Fortran or any other language may be used to access any of the data.

The data to which these inventories pertain (e.g., hourly surface data) are not available on-line (internet, etc). To place orders for data (magnetic tape, cartridge tape, 8 mm tape, diskette, paper copy), please contact our Climate Services Branch.

f) Global Summary of the Day Data



These summary of day data files include the latest month's data, normally available about 1 month after the end of the data month, for over 8,000 worldwide locations. They are accessible through our mosaic/homepage server at -- http://www.ncdc.noaa.gov or through direct ftp connection as follows:

-- open 192.67.134.72
-- login is: anonymous
-- password is: your email address
-- directory for global summary of day:
/pub/data/globalsod

The directory has a "readme.txt" file with information about the contents and individual file names. The data are available as 7 regional files or as 1 file containing all of the data (in ASCII or compressed mode). The daily elements included in the dataset (as available from each station) are:

Mean temperature (.1 Fahrenheit)
Mean dew point (.1 Fahrenheit)
Mean sea level pressure (.1 mb)
Mean station pressure (.1 mb)
Mean visibility (.1 miles)
Mean wind speed (.1 knots)
Max sustained wind speed (.1 knots)
Maximum wind gust (.1 knots)
Maximum temperature (.1 Fahrenheit)
Minimum temperature (.1 Fahrenheit)
Precipitation amount (.01 inches)
Snow depth (.1 inches)
Indicator for occurrence of: Fog, Rain, Snow, Hail, Thunder, Tornado

Other periods of historical summary of day data can be obtained off-line from NCDC. Additional information and complete documentation are available from NCDC.

5. CONCLUSION

NCDC has developed a suite of products and services useful to teachers and educators. These products can easily be added to any earth science curriculum.

NCDC CONTACT INFORMATION

NCDC'S Climate Services Branch is the group responsible for distribution of information about On-Line access. They can be contacted via the following phone number, Internet, electronic mailbox or facsimile.

Please call for latest availability and pricing of any of these products and services.

Telephone Number : 704-271-4800
Fax Number : 704-271-4876
Internet Access : orders@ncdc.noaa.gov
OMNET Mailbox : NCDC.SERVICE

J6.9 The Use Of Hypertext Climatologies To Train Weather Forecasters

Scott A. Straw, and Kenneth R. Walters, Sr.

United States Air Force Environmental Technical Applications Center
Scott Air Force Base, Illinois

1. INTRODUCTION.

The use of hypertext climatologies to train weather forecasters has great promise. Hypertext climatologies provide forecasters information on areas of the world that they may know little about. They discuss general geography of land areas, major meteorological features and climate controls. These major areas are then broken down into smaller climatic regions by season with typical weather and local effects addressed. By putting this information on a computer and providing the ability to "link" or "jump" to specific topics, understanding is greatly enhanced. Graphics can also be included, and by pointing a mouse to a particular area on a graphic, you can jump to text which provides information on the area.

The use of hypertext climatologies has several advantages that allow forecasters to increase their knowledge of remote areas of the world quickly. Thumbing through pages of a narrative climatology while trying to locate information can be time consuming. Hypertext climatologies can enhance the speed with which the information can be located. Hypertext allows the reader to follow trails of information that interest them or are relevant to their task. This is very different from paper documents or books which typically force the reader to move though large numbers of pages to retrieve only a single piece of information.

2. TERMINOLOGY AND DEFINITION

Although easy to use, hypertext is not easy to define. The traditional definition of hypertext is "nonlinear writing or reading". A clearer definition describes hypertext as "a technology for authoring or reading information on a computer screen".

Within hypertexted documents, subjects are interconnected by links which give immediate access between linked topics. A good example of a hypertext document is a "Microsoft Windows" help file. In a paper document you have to turn pages to find more information. The hypertext document is structured so that whenever more information is needed, the user can link to it by clicking on a word, graphic, or phrase on which they need information. This can be described as a non-linear flow.

3. DISCUSSION

Hypertext climatologies promise to be better for training weather forecasters than conventional books. Narrative climatologies are a good example of nonlinear reading. Many chapters refer to other sections in the book. In hypertext terminology these references would be called links. Due to the extensive indexing and organization of most narrative climatologies, multiple references or links can be followed. With conventional books, if the user is not familiar with a term, they have to refer to another location in the book to find it. This is a manually difficult process to follow, and can inhibit the retention of a person trying to study the weather for a particular location. Everything isn't in one place for a person to quickly grasp and retain.

A normal session spent studying the weather for Equatorial Africa might go something like this. Suppose you need to study information for a particular area to which you may deploy. You first look into the index and find Equatorial Africa. You then turn to the correct page, skim over the paragraph headings, and begin reading the material within each paragraph. As you read about the general landmass features, the "great escarpment" is mentioned and you have no idea what this is. You locate a map a couple of pages into the chapter and find the "great escarpment". It turns out to be a mountain range that runs along the western coastal region of Africa. You have lost your place in the

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text, so now you have to retrace your steps. Another three minutes into the reading there is a reference to "savanna area" and a "savanna plain". You're curious as to what a "savanna" is, so you turn to the reference section in the back of the book and find that "savanna" is defined in the beginning of that chapter. You find out that "savanna" is a subtropical and tropical grass area. Now you return to the original text, move onto the temperature of the Equatorial Africa, and find that you don't understand the term "maritime tropical airmass". You now have to concentrate on looking up "maritime tropical airmass". While finding out what the meaning of the phase is by referencing the back of the book, you remember seeing "continental tropical airmass" and look this up also. Back you go again to find the correct spot you were at before you were sidetracked.

Now for contrast, consider this description of the same research into Equatorial Africa using a hypertext climatology. You click on the icon that starts the program. Once the program is running you are led into the table of contents. From this point you choose Equatorial Africa. You are then given a chapter table of contents or you can choose to read through the chapter as one continuous document. You choose to read through the chapter as a continuous document and are shown the general landmass features. When the "great escarpment" is mentioned, you click on the phrase and a window appears with information on the "great escarpment". It is a mountain range that runs along the western coast of Equatorial Africa. You now close the window and the mouse is pointing to the exact position where you stopped reading. You continue your reading and come across a reference to "savanna area" and a "savanna plain". You click your mouse on the phrase and find that "savanna" is a subtropical and tropical grass area. You close this information window and continue scrolling through the document. Now you move onto the temperature of the Equatorial Africa and find that you don't understand the term "maritime tropical airmass". By clicking your mouse on this phrase you are immediately linked to the chapter that explains about tropical airmass. You also note that "continental tropical airmass" is explained. You press a function key and you are back in the text at the point where you left.

You can see by this example that the hypertext document can be quickly studied without distractions Everything is interwoven and right at your fingertips. By not continually turning pages to reference the unfamiliar, you have the chance to absorb what you are studying.

Hypertext is a communication medium that draws its basis from conventional writing but surpasses it in the depth that it offers the reader. However, unlike conventional writing, hypertext is nonlinear in nature. It eliminates the one basic assumption that pervades all paper based writing, that, is "one page comes after the other". A hypertext climatology is designed to be explored by the reader. There is not a definite orderly progression of pages in a hypertext document. Readers are free to follow whatever paths of information they feel are significant.

Neophyte users sometimes fail to recognize that a hypertext climatology is very similar to a book. The problem is that a reader may feel they are not in control of the hypertext document as they believe they are over a book. Once a user becomes confident in both the computer system and the document interface, they are much more likely to use a hypertext document than a paper document.

Hypertext documents contain many additional useful tools. One provides a method to leave electronic "notes" attached to a topic or document. This is the electronic equivalent of writing in the margin of a book. Notes allow forecasters to add detail to the hypertext climatologies. The "home" command returns the reader to where he began reading. It is very useful to quickly jump back to a document's beginning. Another function in the hypertext climatology document that is similar to a book is the bookmark. When you find a section of the book that you would like to return to, the bookmark gives you the ability to jump to that location at any time. Hypertext climatologies can also include tests. End of chapter tests can help improve the level of understanding. A question can be linked with a specific topic. If the student answers the question wrong, the student will be sent to the text from which the question was developed.

4. SUMMARY

By putting narrative climatologies on a computer with the ability to be able to link or jump to specific topics, depth and speed of comprehension is greatly enhanced. Hypertext allows the reader to follow trails of information that interest him or are relevant to his task. This is very different from paper documents, which typically force the reader to move though large numbers of pages to retrieve only a

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single piece of information. It has been said that the human mind operates by association. With one item in its grasp, it snaps instantly to the next that is suggested, in accordance with some intricate web of trails connected with the brain. Man cannot hope to fully duplicate this mental process artificially, but he certainly ought to be able to learn from it. This technique is the basis of hypertext documents.

J6.10

A NATIONWIDE NETWORK OF AUTOMATED WEATHER STATIONS: USING REAL-TIME WEATHER DATA AS A HANDS-ON EDUCATIONAL TOOL

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1. INTRODUCTION

In today's information age, we are required to collect, analyze and interpret vast amounts of data. To prepare students for this world, educators are challenged to bring real-world concepts and experiences into the classroom. Automated weather systems lend themselves readily to this task. Teachers and students have found that networks of automated weather observation stations in schools can provide a hands-on, technology based approach to learning that interests students. The networks also provide an avenue to TV meteorologists and businesses for creating a meaningful partnership with the educational community that benefits all.

2. THE PROBLEM

Today's teachers are competing for students attention. Advanced technology, often outside of school, including computer and video games, television, and multimedia seems to be more enticing than a science textbook. Motivating students to learn is a constant challenge faced by educators. Many traditional teaching methods do not capture the interest of students.

Teaching problem solving techniques to students is critical in our complex and constantly changing world. Finding examples of data to collect, analyze and interpret can be difficult. Many times, problem solving exercises are awkwardly constructed and unmeaningful because the data is not relevant to real world situations.

Many students find science and mathematics concepts intimidating, abstract, and too difficult to comprehend. Students are often discouraged and turned off to exploring math and science at an early age.

In addition, school systems throughout the country are faced with budget shortfalls, limiting the ability to bring current technology into the classroom. Yet, educators recognize that the use of high technology in the classroom is essential for today's students to succeed tomorrow.

3. AN APPROACH

Now that we have defined the problem, let us employ some of our own scientific problem solving skills to formulate a possible solution. We should develop a hypothesis, test it, interpret and analyze our findings and then draw conclusions based on them.

We need to incorporate a subject that interests all -- state-of-the-art technology, computers and software, captivating teaching techniques, broadcast television, and business/educational partnerships (see Figure 1: Concept).

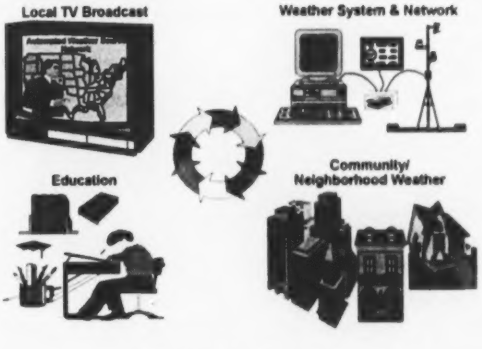

Figure 1 - Concept

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4. A POSSIBLE SOLUTION

Weather affects everyone's life: the student hoping for snow, the pilot preparing to land, the landscaper planning a days work... Weather is not intimidating! Weather is in the news! We all relate to it in some manner on a daily basis (see Figure 2).

State-of-the-art automated weather stations, networked through telecommunications, can provide the technology we need. Advanced software to access real-time data from these networked weather stations will provide the computer interface. Data displays will use interesting, color graphics that are informative, easy to understand and allow for data interpretation and analysis.

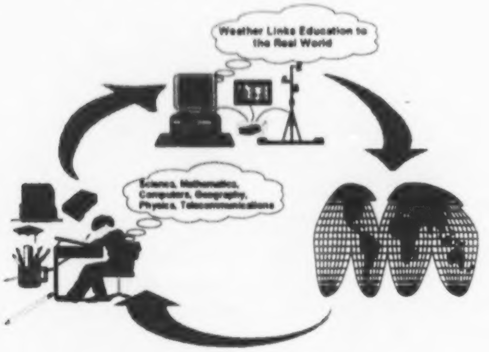
Weather Links Education to the Real World
Science, Mathematics, Computers, Geography, Physics, Telecommunications

Figure 2 - Educational Impact

Interdisciplinary lessons can be developed using the latest teaching techniques utilizing the weather stations and software. Why not provide software to television meteorologists to access and broadcast real-time data from the network of weather stations in schools? This would instill a sense of pride in the community and school and further motivate the students.

In addition, this concept can obtain business support! Businesses recognize that their future depends on an educated workforce who are literate in many disciplines, most particularly the sciences and technology. They are willing and eager to partner with schools to achieve these goals.

5. ESTABLISHING A NETWORK

The approach outlined above is presently being setup throughout the United States. Meso-networks of fully automated weather observation stations are being established in schools throughout the country (see Figure 3). Over 45 cities have initiated school weather networks.

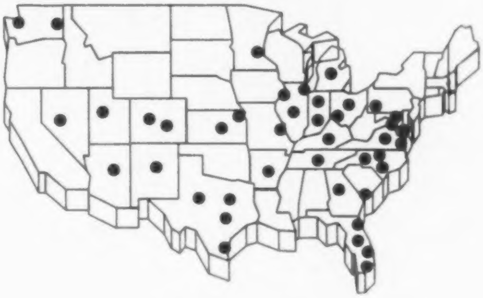

Figure 3 - The National Network

The Washington / Baltimore area is leading the way with a mesonet of more than 130 stations (Bob Ryan's 4-WINDS Network on WRC TV, see Figure 4).

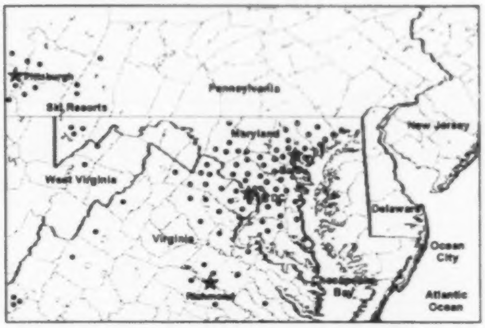

Figure 4 - Washington/Baltimore Area Network

In addition to schools being able to access and use real-time weather data in the classroom, broadcast meteorologists also participate in the program by presenting viewers with "live" weather conditions from neighborhood schools. Students and teachers are excited by the broadcast exposure, and they translate that excitement into an enhanced interest in the sciences. Businesses are also participating by partnering with broadcasters and schools.

The following are several examples of active business/educational partnerships: Giant Food and Hughes Information Systems (Washington DC area); Fifth-Third Bank (Dayton, Ohio); Best Buy (Chicago, Illinois); and Motorola Corporation (Austin, Texas).

6. THE SYSTEM

The system used for this concept has been developed by Automated Weather Source (AWS), Inc. The AWS system consists of a sensor suite (temperature, relative humidity, barometric pressure, wind speed and direction, precipitation and light intensity), data logger, digital display, modem and software for a PC or Macintosh computer. Data is transferred throughout each mesonet through telecommunications.

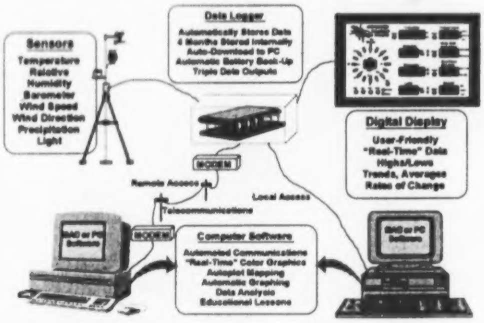
Sensors
Temperature
Relative
Humidity
Barometer
Wind Speed
Wind Direction
Precipitation
Light
Data Logger
Automatically Stores Data
4 Months Stored Internally
Auto-Download to PC
Automatic Battery Back-Up
Triple Data Outputs
Digital Display
User-Friendly
"Real-Time" Data
Highs/Lows
Trends, Averages
Rates of Change
MODEM
Remote Access
Local Access
Telecommunications
MODEM
MAC or PC Software
Computer Software
Automated Communications
"Real-Time" Color Graphics
Autoplot Mapping
Automatic Graphing
Data Analysis
Educational Lessons
MAC or PC Software

Figure 5: System Components

The AWS software has been specifically designed by engineers and teachers for use in education. Students can view real-time weather data from their own weather station or any other station on the school weather network. Interdisciplinary lessons based on the system and software are included with the system and incorporate the latest teaching techniques.

The automated data logging features of the system are critical to education. The system can store internally up to four months of weather data, which can be effortlessly transferred to the computer. With the software, schools can maintain a permanent record of hourly weather conditions at any site on the network.

All data can be plotted and graphed over varying time periods, providing excellent tools for mathematics and science curriculum. The data also provides a foundation for formulating weather predictions and subsequently analyzing weather events.

7. EXAMPLES OF USE

This section of the paper will provide and discuss a few examples of incorporating data generated by automated weather stations into classroom curriculum. The examples given here are just a small subset of what is being done and what can be done with systems of this type.

The beauty of an automated weather system and network is that it can be incorporated into all facets of curriculum, not just math and science. The system can be used at all grade levels and with students of all skill levels. Many schools use an interdisciplinary approach, that is, incorporating the system in all disciplines and subjects and tying the lessons/concepts together with a single theme.

7.1 Language Arts and Public Speaking

Almost all schools participating in the program use the weather system and software for morning announcements. Students use the software to gather weather data from schools throughout their region and produce a weather report to be broadcast to the entire school. Upper level students also include a forecast with their weather report.

Some schools have in-house video equipment and are capable of producing their own TV weather broadcast. One school in Jacksonville, Florida has documented a case in which dropout prevention students consistently arrived 30 minutes early to school to use the weather software and produce a daily TV weather broadcast, No small feat for students at risk of dropping out of school!

7.2 Social Studies

An interesting lesson being performed by many schools ties social studies to math and science. Students are asked to hypothesize how weather may affect a number of social variables, including student attendance, student behavior, test performance, or even economic performance of various industries.

Students use the weather station and software to track and graph weather variables over time. They also collect data from other sources to track the social studies parameters. The students correlate and analyze the data and draw conclusions. This is a fine example of a real-world problem that is readily integrated into the classroom.

7.3 Geography

The network of weather stations fits perfectly into geography studies, as the computer software allows any weather variable to be auto-plotted on a variety of custom maps. Students can access current weather data from any station on the network. They then can plot the data on a map and discuss the results. Many students are challenged to explain the reasons behind the variety of weather data exhibited on the maps. Figure 6 depicts an example of a weather mapping display.

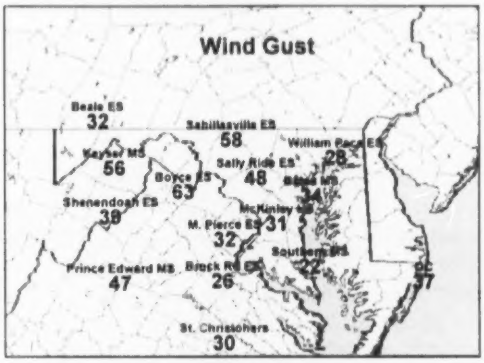

Figure 6 - Example Weather Map

In another higher level thinking activity, students were given network data in the form of tables and asked to associate it with unmarked locations on a map. Students were required to draw upon their knowledge of climate, weather and geography to arrive at conclusions.

7.4 Math and Science

The opportunities to incorporate the weather system and network into math and science curriculum are endless, so just a few will be presented here.

Graphing and interpreting data can take on special significance and generate a great deal of interest when severe weather phenomena occur. Using the weather station's data logging and software features, students were able to collect and analyze data from the "Blizzard of 93" that traveled up the East coast of the US, as shown in Figure 7. While only temperature and barometric pressure are shown here, students discovered interesting correlations by plotting several variables, including, barometric pressure rate, wind speed, and relative humidity.

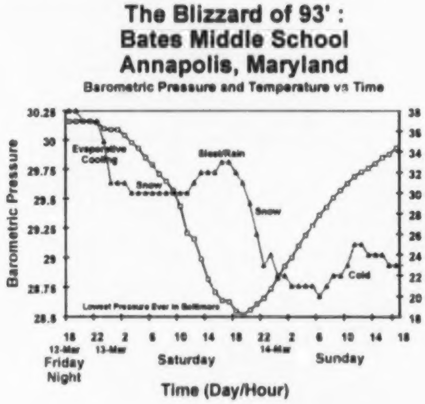

Figure 7 - Blizzard Analysis

In fact, a plot of temperature and relative humidity at the beginning of the snow storm produced several unique features. One of particular interest was evaporative cooling of the atmosphere (an exothermic reaction) as the snow began to fall, producing a nice link between science and chemistry.

Interpreting data many times requires statistical analysis. Students often do not understand statistical terms like mean, median and mode. When lessons dealing with statistics use data from the weather network, these terms are given concrete meanings to which the students can relate.

Understanding relationships between variables in science and math is very difficult for some students. Weather data provides a variety of fundamental relationships that students can readily relate to and understand. Linear, cyclical, proportional, inversely proportional, and cause and effect relationships can be demonstrated with ease using the weather system.

Cyclical relationships can be demonstrated by plotting hourly temperature data over an extended period of time (3 days or more). A cause and effect relationship can be shown by plotting hourly light intensity and temperature data over a one day period, as shown in Figure 8. An increase in the light intensity causes an increase in the outdoor temperature.

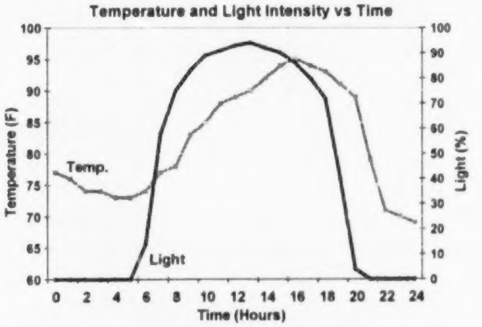

Figure 8 - Cause and Effect Relationship

Plotting temperature and relative humidity together depicts an inversely proportional relationship in most cases, as shown in Figure 9 with two days plotted on the X-axis.

Since the weather stations also track and log hourly change rates, the data fits naturally into high school level calculus curriculum. Students can plot hourly temperatures along with the hourly temperature change rates and grasp the concept of a derivative in all its many facets. Monthly climate data (highs and lows for each day) can be integrated to compute heating and cooling degree days as well.

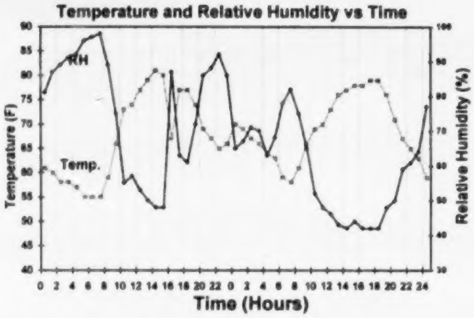

Figure 9: Inversely Proportional Relationships

8. CONCLUSIONS

While feedback from students and teachers continues to come in from all over the country, initial results look extremely promising. Weather provides a perfect window of opportunity for teachers to link a relevant real world environment with state-of-the-art technology via an interdisciplinary curriculum. This system represents an example of authentic testing.

Networks of automated weather observation stations in schools provide students and teachers with an excellent tool for a concrete, hands-on approach to learning. The weather data generated by these systems interests students, easy to is understand and lends itself to use in any curriculum.

9. FUTURE PLANS

With the support of educators, TV broadcasters, and corporate sponsors, the school weather network will continue to expand to cover the entire nation and beyond. AWS will also be introducing a newsletter and an enhanced computer bulletin board system to help AWS users share ideas and ask questions about the weather.

Many schools have recognized the benefits of the AWS system and have incorporated it into their curriculum planning. As the number of students and teachers involved in the program increases, so will the innovative ideas for the application of this system.

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APPLICATIONS OF SATELLITE IMAGERY AND REMOTE SENSING IN ENVIRONMENTAL /SCIENCE EDUCATION: *AN EARTH SYSTEMS SCIENCE APPROACH*

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1. INTRODUCTION

The purpose of this paper is to examine the use and effect of satellite imagery, direct read out data, and other remote sensing sources of real time data, and their impact on issues identified in science education research. Imagery generated from international remote sensing satellites provide real time data for monitoring global natural resources and other atmospheric and environmental phenomena. These images present *interdisciplinary* opportunities for students and teachers to examine and study Planet Earth on a local to global scale, and opens a new chapter in the field of ***environmental interpretation***. The following observations, review of current literature, and documentation of technological developments, lead to the following conclusions, and provide for the foundation of this paper.

- The science education community, as well as the nation, is calling for reform in science education.
- There is rapidly growing concern for environmental issues ranging from the local to global level, and a call for mandatory incorporation of environmental education in the K-12 curriculum.
- There is a call for incorporation and application of new technologies in the classroom.
- Costs of powerful (high capability) computer systems are in rapid decline.
- There exists today, an archive of scientific environmental data.
- NASA and NOAA have planned and budgeted for future environmental monitoring satellites that provide time data through the turn of the century.

2. RATIONALE

In 1983 an advisory council of NASA established an Earth Systems Sciences Committee to review the science of Earth as an integrated system of interacting components. The stated goal of Earth Systems Science is to "obtain a scientific understanding of the entire Earth System on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales." NASA's Earth Observing System Program states, " observations from space have provided extensive global views that allow us to study the Earth as a unified system. This systematic approach to Earth Science will help us understand how local activities might produce effects on a worldwide scale. The goal is to understand relationships among atmosphere, land, and ocean processes on scales that range from chemical reactions to global climate change. To do this, earth science needs an interdisciplinary approach that combines the classical disciplines of physics, chemistry, and biology." In 1990 the U.S. Congress adopted the Global Change Research Act. The U.S. Global Change Research Program was established "aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment ..." with a recommended FY 1995 budget of $1.8 billion. The U.S. Global Change Research Program identifies their scientific objectives as follows:

- Establish an integrated, comprehensive long-term program of documenting the Earth System on a global scale.
- Conduct a program of focused and exploratory studies to improve the

understanding of the physical, chemical, biological, and social processes that influence the Earth System changes and trends on global and regional scales.

- Develop integrated conceptual and predictive Earth-System models on global and regional scales.

The education component of this program has identified the following objectives:

- Involve public and institutional decision makers in program planning and examination of policies and options
- Expand public awareness of global change, including awareness of the prominent issues, their scientific complexity, and research needed for predicting consequences and evaluating national and international policy options for responding
- Train future scientists, engineers, and educators by promoting understanding among educators and decision makers of the multidisciplinary nature of global change issues and solutions

The FY 1995 U.S. Global Change Research Program budget allocates funding to the following federal agencies to accomplish these goals, and therefore have an educational responsibility:

- Department of Agriculture
- Department of Commerce/NOAA
- Department of Defense
- Department of Energy
- Department of Health and Human Services/National Institutes of Health
- Department of Interior
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation
- Smithsonian Institution
- Tennessee Valley Authority

As we approach the 21st Century, the monitoring of the planet's environmental systems has been coordinated into a massive scientific and technological undertaking. The "Earth Observing System" (EOS), is an internationally coordinated, multidisciplinary spacebourne program that will study the interactions of Earth's land, sea, and atmosphere, and document these changes in the global environment in an initiative called "Mission to Planet Earth." Early documents did not include the K-12 curriculum as a potential user. More recently. the document "Public Use of Earth and Space Science Data over the Internet" (NASA 94) which was a solicitation to "stimulate broad public use, via the Internet, of very large remote sensing databases maintained by NASA, and other agencies to stimulate US. economic growth, improve the quality of life, and contribute to the National Information Infrastructure," was introduced. The announcement identifies its purpose and focus. The potential applications of remote sensing databases, and areas of interest include: atmospheric, oceanic, and land monitoring; publishing; agriculture; forestry; transportation; aquaculture; mineral exploration; land-use planning; libraries; cartography; **education (*especially K-12*)**; entertainment; environmental hazards monitoring; and space science data applications" (CAN-OA-94-1, NASA, 94.) This project is representative of the future impact of dialog between teachers, students, schools, and scientists in science education.

3. APPLICATIONS, RESOURCES AND TOOLS

A Shift in the Paradigm

Three distinct educational disciplines have been evolving over the past three decades As we approach the 25th Anniversary of Earth Day (April 22, 1995), Science Education, Technology Education, and Environmental Education have the opportunity to unite their common educational goals and objectives and embark in a new direction leading education towards the classroom of the 21st Century, a classroom where students practice real science, in real time, interacting with international scientists representing an array of agencies and organizations. The development of thinking skills, cooperative and hands-on learning utilizing the power of technology, while applied to real world applications can lead to improvement in , math, and geography as well. Archives of scientific environmental data exist in a variety of formats, and plans are in place that will increase the quantity, quality, and availability of such environmental data.

Technological advancements, which include satellite receivers, cable/television, radio, and telephone lines (traditional and fiber optic) make it possible to receive, and exchange, real time data in the classroom within reasonable economical limits. The increasing availability additional formats, such as CD-ROM, allows one to access and examine achieved data sets, consisting of a variety of historical environmental data and information. It is important to note that if the required technology is not yet available in the schools, many resources exist in printed form. Agencies have developed monographs, resource guides, curricula, and other supporting teaching materials on global change, thus allowing students to engage in similar activities using the Earth Systems Science approach, using *recent* data and images usually available through educational outreach programs within both industry and government. The K-12 audience is not only capable of utilizing these technologies and information, but research indicates that students exhibit higher interest, and therefore motivation in their science studies. The success and necessity of Science Technology and Society (STS) format in science education is well documented. An Earth Systems Science Approach satisfies the STS agenda.

One of the national educational goals in America is for students to globally place first in science education by the year 2000. This of course has spurred the Science Education community to examine what exists, and begin exploration of possible new directions. National science standards have been drafted and will likely be implemented. An Earth Systems Science approach to science education models current science research. Part of the educational agenda is to address the need for future generations to move into the scientific research community. As students develop proficiency in the identification, acquisition and applications of available real time data, student initiated research can begin. Students have the capabilities to globally observe, record, and exchange data, which may lead to solutions of global environmentally related problems. Technology provides the forum for rapid exchange of information. In the process, students have exposure to real issues, and real applications, factors that have been identified in science education research as improving student interest and performance. Ground truth verification of satellite data is an essential component of data reliability, and therefore, students from around the planet may have the opportunity to contribute to the process.

Satellite Imagery/Direct Readout Data

NASA and NOAA have a full slate of environmental data gathering satellites planned to be operation by the turn of the century, thus opening the door to advance opportunities to study/monitor our planet, and revolutionizing the educational opportunities in environmental science. Students can *today* utilize NOAA weather satellite data and experience the following practical applications of science concepts and principle which include but are limited to:

- Develop a knowledge and understanding of environmental satellites, their operation, and application of data
- A hands-on application of data processing skills and work with computers
- Application of satellite images as they apply to: weather forecasting, identification of land masses, location of geographical areas via coordinates, tracking weather phenomena, and developing forecasting skills from a visual data base
- Develop a knowledge and understanding of **global** conditions and how environmental factors such as weather are globally interconnected
- Identify visually, weather phenomena such as: cold, warm and stationary fronts, areas of precipitation, hurricanes, tropical depressions, global cloud formations, and global weather movement
- Apply meteorological terminology, and National Weather Service reports/data to observable satellite images
- Develop and conduct individual research projects using data and/or the technology to expand student experiences in the areas of Meteorology and/or the use of technology
- Acts as a demonstration project to encourage and develop interest by women and other minorities in the study of environmental sciences

NASA's "Mission to Planet Earth," when fully functional, will produce environmental data that includes ocean circulation and atmospheric chemistry, the ozone hole, ocean productivity, marine winds, tropical rain, influence of clouds, heat transport, rainfall patterns, atmospheric CO2, and seeks to answer the questions of how is the atmosphere changing, and the role of the solid earth.

Geographic Information Systems (GIS)

GIS applications have advanced considerably in the past two years. Once viewed as an exclusive domain of researchers and highly experienced professionals in the field, it is today available to the K-12 community. *ArcView* and *ArcData* CD ROM software, marketed as a "geographic exploration system," is available to K-12 schools enabling students and teachers to create an almost complete GIS database. Applications identified in the science curriculum include:

- Expand analyses of environmental relationships by displaying the micro and macro systems as they occur
- Expand local environmental analyses by seeking similar patterns in other places
- Study the impact on visible patterns altering the electromagnetic radiation received in satellite imagery
- Overlay satellite imagery with ground mapping to examine the impact of environmental characteristics on people and vice versa

ArcData products include data sets "structured to fulfill a wide range of map display, query, and analysis applications. Regional, national, and global analyses can be performed using the demographic, economic, and environmental data sets, and can be supplemented with other sources from specific thematic mapping applications." Electronic mapping can help students learn concepts in geography, science, math; develop data analysis, visualization and spatial reasoning (Barstow). It enables the student to explore topics of local regional, and global impact.

DataStreme

DataStreme is a cooperative effort between **Project ATMOSPHERE** of the *AMS* and cable television's The Weather Channel. The WSI Corporation is participating in the project by providing the access and free use of The Domestic Data Service data stream it delivers to The Weather Channel. During the 1993-94 school year, a pilot study designed to "investigate the educational potential of *real-time scientific data* for use across the curriculum K-12 was implemented. The objectives are as follows:

- The determination of the technical and economic feasibility of delivering a real-time meteorological data stream to schools across the country at no additional recurring costs to schools
- The investigation of the educational; potential of using real-time scientific data in school learning environment through the development, implementation, and evaluation of prototypical instructional strategies and materials
- The preliminary identification and teaching of understandings and skills employed in the processing, analysis, evaluation, application, and interpretation of a continuous data stream to seek answers, trends and predications.

THE GLOBE PROGRAM

The *GLOBE* Program (**G**lobal **L**earning and **O**bservations to **B**enefit the **E**nvironment) introduced by Vice President Al Gore on April 22, 1994 will link students worldwide in an effort to monitor changes in the world's environment. The objectives of GLOBE are:

- To enhance the collective awareness of individuals throughout the world concerning the environment
- To increase scientific understanding of the Earth
- To help all students reach higher standards in science and mathematics

A worldwide network of K-12 students will making environmental observations including temperature, wind speed and direction, precipitation, land cover, water chemistry, and soil moisture content. Via Internet, satellite transmission, and television the network will support:

- The acquisition of environmental data by students
- Transmission of data to processing sites in the U.S. and other countries
- Distribution of vivid, graphical environmental pictures of the world to students at their schools
- Distribution of student data to environmental scientists throughout the world.

4. SUMMARY

In order to understand global change and the demands on human activity, the science community is documenting global environmental systems so we can better comprehend how the Earth works as a system. The science education community can likewise respond by encouraging students to begin use the data and technology in the classroom that will prepare them to transition into the rapidly emerging professions of the 21st Century. This paper did not venture into the resources available via the Internet. There exists today, a wide menu of images, real time data and diversity information and products that is growing at rapid rates. An Earth Systems approach applies environmental systems principles to traditional Earth Science, Biology, Chemistry, and Physics core proficiencies, and more importantly provides the structure, or focus of instruction. It is Science with a purpose. The Earth Systems Science Approach is science for the 99%. The Earth Systems Science approach to environmental /science education will apply, model and teach skill proficiencies that are representive of the science research community. Equally as important, the Earth Systems approach will develop interest and prepare students for careers in the science, technology, and environmental fields, while fostering an environmentally literate and conscious society, leading towards better local and global decision makers.

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THE GREENHOUSE EFFECT VISUALIZER: A TOOL FOR THE SCIENCE CLASSROOM

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1. INTRODUCTION

The Greenhouse Effect Visualizer (GEV) is designed to help students visualize data sets related to the earth's energy balance. This work was inspired by the benefits scientific visualization have provided to scientists in discovering patterns and presenting the results of their work to broad communities. The hope is that scientific visualization can provide equal assistance to students trying to learn science. The philosophy underlying this approach links learning with practice. Hence, students are encouraged to learn science initiating and pursuing scientific questions and through interacting with the scientific community. This approach is by no means new, the difference is the attempt to ease the task through the assistance of selected technologies. This framework is basic to the Collaborative Visualization Project (Pea, 1993) of which the GEV is a part. This paper describes the GEV, including its data sets, models and visualizations, supported operations on data, and suggested uses. In addition, since the GEV is still very much under development, current shortcomings are described along with potential remedies.

2. WHY THE GREENHOUSE EFFECT?

The greenhouse effect has become the focus of an international research effort in the scientific community that views the earth and its atmosphere as a unified system affected by the fuel policies of industrial and emerging nations (Silver and DeFries, 1990). This intertwining of scientific and social concerns is useful since it provides diverse *hooks* or entryways for students to become involved with science. Optimally, this variety allows students to choose an angle that combines with their existing interests, yet relates to a common topic. For example, one project might propose a cap on carbon-dioxide emissions, while another evaluates the cap's impact on developing nations. Projects of this type involve substantial amounts of science, yet are not traditional science projects, since they integrate social and political concerns. It is hoped that integrated projects like these will help students to view science within a social context, rather than as isolated formulas.

3. WHY SCIENTIFIC VISUALIZATION?

Students need specialized resources in order to participate in scientific practices. This need is documented by sociologists of scientific knowledge who have analyzed the role of specialized representations in negotiating scientific questions (Latour and Woolgard, 1979). Their findings show that when a scientific community adopts a new representation, it signifies an important change in the field. Arguably, scientific visualization is such a change for atmospheric science. Hence, giving students usable access to it can help them to understand and perform atmospheric science. In practice, the most common usage of visualizations is to portray scientific processes that vary spatially. This allows increasing or decreasing values to be easily picked out through noticing distinctive colors and patterns. As detailed below, these observations can help students to understand processes involved in the greenhouse effect.

4. DATA SETS IN THE GEV

The GEV data is based on the Earth Radiation Budget Experiment (ERBE; Barkstrom, 1984) data sets. These data sets provide monthly means of the quantities involved in the radiation balance through which the earth system reflects, absorbs, and re-emits radiation. In addition, surface temperature is provided from European Common Model World Forecast (ECMWF) data. The data sets provided by the GEV are:

1. Sunlight coming to earth (insolation)
2. Reflectivity of Earth-Atmosphere system (albedo)
3. Reflected sunlight (reflected shortwave radiation flux)
4. Absorbed solar radiation (insolation minus reflected sunlight)
5. Surface temperature
6. Outgoing terrestrial radiation (longwave radiation flux)

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7. Net radiation (outgoing minus net incoming radiation)
8. Greenhouse effect amount (amount of energy retained in the atmosphere)
9. Greenhouse effect percent (percent of terrestrial radiation flux that is retained in the atmosphere)

These data sets were selected to help students understand how increased greenhouse effect could increase surface temperatures.

4.1 *Models in the Greenhouse Effect Visualizer*

The GEV offers three models under which to view the above data sets:

1. Earth without atmosphere
2. Earth with atmosphere but no clouds (i.e. clear atmosphere)
3. Earth with atmosphere and clouds

This sequence of models is motivated by order of magnitude effects involved in producing our climate. This is demonstrated by calculations that show that the global temperature of an atmosphere-free Earth would be around 254° Kelvin.. Adding an atmosphere brings this chilly average up above freezing, to around 276° Kelvin (freezing is 273° Kelvin). The effect of clouds is to refine this number still further (exactly how is still being debated). The main point is that the models provide successive approximations to the Earth climate. The primary basis has been the black-body model which relates energy to the fourth power of temperature. The specific formulas used are listed in Table 1. Each model is now analyzed in turn, by discussing the derivation of the data sets, current limitations, and potential remedies.

4.2 *Model 1: Earth without an atmosphere*

An earth without an atmosphere would have a simple energy balance where the amount of incoming radiation would equal outgoing radiation. This allows the calculation of surface temperature using a black body model as follows:

$$T = \sqrt[4]{\frac{(1-\alpha_{CLR})\,S}{\sigma}} \qquad (1)$$

where σ is the Stephan-Boltzman constant, S is the solar constant and α_{CLR} is clear sky albedo, so $(1-\alpha_{CLR})\,S$ is the absorbed solar radiation. The use of α_{CLR} to model albedo without an atmosphere is a substantial simplification, since α_{CLR} includes atmospheric gases, such as, water vapor and carbon-dioxide. However, it is useful in identifying high albedo areas, such as, polar caps and deserts. The full set of derivations used to calculate GEV data sets from ERBE data, for this model and the others, is in Table 1. Note that the greenhouse effect amount and percent are zero for this model. This is definitionally true, since greenhouse effect refers to the energy trapped by the atmosphere and this model specifically excludes an atmosphere. Similarly, the net radiation is zero as the outgoing radiation is assumed to equal the incoming radiation.

The primary problem with this model is that it does not take into account thermal inertia; this is particularly significant for the poles and oceans, since ice and water retain significant amounts of heat. A possible solution is to use the current monthly mean radiative calculation for land (due to its low thermal inertia) and use annual mean radiative calculations for water (due to its high thermal inertia). The poles are more complicated because of the latent heat of ice. The overall temperature cannot rise until the ice has melted. A several month moving average could be used to smooth out the excessively quick changes, thus taking into account the time needed to melt and freeze polar ice.

4.3 *Model 2: Earth with an atmosphere, but no clouds*

The presence of an atmosphere increases the surface temperature, since the atmosphere traps outgoing terrestrial radiation, but allows incoming solar radiation to pass through. The atmosphere is here modeled as a black body, thus all terrestrial radiation is assumed to be caught. Further, when the atmosphere re-emits the trapped terrestrial radiation half is sent to outer space and half back to the earth. This means the measured outgoing longwave radiation flux equals incoming longwave radiation. This allows the surface temperature to be calculated using a black body model as follows:

$$T = \sqrt[4]{\frac{(1-\alpha_{CLR})\,S + F_{CLR}}{\sigma}} \qquad (2)$$

where F_{CLR} is incoming longwave radiation flux (taken as equal to observed outgoing longwave flux) and $(1-a_{CLR})\,S$ is again the absorbed solar radiation. This model uses a very simplified view of the atmosphere. In particular, the atmosphere is modeled as a single layer, hence the temperature profile (or lapse rate) of the atmosphere is not taken into account. This leaves little room to answer a natural question from students: "If surface temperature is based on a radiation balance and your model already assumes a black body atmosphere (i.e. one that absorbs all terrestrial radiation), why would increasing amounts of CO_2 make any difference?" Indeed, in this model it would not cause a difference (Horel and Geisler, 1993). Rising levels of CO_2 in the atmosphere make a difference because as they raise the temperature of the atmosphere, the temperature at the surface of the earth also rises due to the vertical temperature profile of the atmosphere (i.e., a lapse rate of around 6.5°C per kilometer). The proposed

	Model 1 Earth without atmosphere	Model 2 Earth with atmosphere but no clouds	Model 3 Earth with atmosphere and clouds
Insolation	S	S	S
Albedo	α_{CLR}	α_{CLR}	α
Reflected Shortwave	$\alpha_{CLR}S$	$\alpha_{CLR}S$	αS
Absorbed Shortwave	$(1 - \alpha_{CLR})S$	$(1-\alpha_{CLR})S$	$(1-\alpha)S$
Outgoing Longwave	$(1 - \alpha_{CLR})S$	F_{CLR}	F
Net Radiation	0	$(1 - \alpha_{CLR})S - F_{CLR}$	$(1-\alpha)S - F$
Surface Temperature	$\sqrt[4]{\frac{(1 - \alpha_{CLR})\ S}{\sigma}}$	$\sqrt[4]{\frac{(1-\alpha_{CLR})\ S + F_{CLR}}{\sigma}}$	T
Greenhouse Effect Amount	0	$(1 - \alpha_{CLR})\ S$	$\sigma T^4 - F$
Greenhouse Effect Percent	0	$1 - \frac{F_{CLR}}{(1 - \alpha_{CLR})S + F_{CLR}}$	$1 - \frac{F}{\sigma T^4 - F}$

Key to data sets (source):

S:	Insolation (ERBE)
α:	Cloudy albedo (ERBE)
α_{CLR}:	Clear albedo (ERBE)
αS:	Cloudy outgoing shortwave radiation flux (ERBE)
$\alpha_{CLR}S$:	Clear outgoing shortwave radiation flux (ERBE)
F:	Cloudy outgoing longwave radiation flux (ERBE)
F_{CLR}:	Clear outgoing longwave radiation flux (ERBE)
$(1-\alpha)S - F$:	Cloudy net radiation (ERBE)
$(1-\alpha_{CLR})S - F$:	Clear net radiation (ERBE)
T:	Surface temperature (ECMWF)

Table 1: Formulas used to calculate data sets

solution to these problems is to use a more sophisticated model of the atmosphere provided by NCAR. This model parameterizes outgoing longwave radiation flux based on atmospheric temperature, relative humidity, and CO_2. The plan is to use tropical, mid-latitude, and polar reference profiles for temperature and humidity. This would provide a surface temperature data set that a student could adjust based on the CO_2 level. In addition, the model-based result should differentiate between temperature increases caused directly by CO_2 and the forced increase due to water vapor which is the feedback mechanism that occurs when surface temperature increases. Separating out the direct temperature increase from the forced increase allows students to differentiate direct effects from feedback effects. Further, the forced effects only occur after a timelag, due to the earth's thermal inertia. It is this lag that provides a window for compensating effects that could reduce the predicted surface warming (e.g., increased albedo from clouds)*.

4.4 *Model 3: Earth with an atmosphere, including clouds*

Although considered here as a model, this category is closer to observations. The surface temperature is not calculated from ERBE data sets, but based on data from the ECMWF. A strength of using observed data is that these data sets can be used by students to study a wide variety of projects. For example, by supplying several years more of data

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* Thanks to Roy Jenne of NCAR for emphasizing this distinction and its pedagogical value.

(currently only 1987 data is provided) El Niño effects could be studied. More detail on using the GEV for activities is provided below.

4.5 *Greenhouse Effect Data Sets*

Measurement of greenhouse effect is given in two ways (for the models with an atmosphere which produce a greenhouse effect). First, a measurement of the energy contained in the atmosphere due to greenhouse effect is provided by subtracting the top of the atmosphere longwave radiation flux from terrestrial longwave flux. This is called the greenhouse effect *amount*. Second, the greenhouse effect is shown as the fraction of energy leaving earth that is retained in the atmosphere, calculated by subtracting from one the ratio of top of the atmosphere longwave radiation flux divided by terrestrial longwave radiation flux. This is called the greenhouse effect *percent*. Figure 1 shows the greenhouse effect percent for July, 1987; equations for these data sets are listed in Table 1.

5. VISUALIZATION AND MANIPULATION OF DATA SETS

The GEV provides visualizations of all the data sets described for the three models, see Figure 1 for an example*. Several features have been included to increase comprehensibility. In particular, the color palette, located below the visualization, records the minimum and maximum data set values keyed to their respective colors. Further, all numbers are listed with their appropriate units (e.g. watts per meter squared). Specific data values pop up on the color palette when the student clicks on the visualizations; the latitude and longitude are given by call-out lines.

A number of enhancements are planned to allow further manipulation of the visualizations and their underlying data by students. First, is the ability to compute the average on parts of the data by sweeping out an area. This provides a mean to convert part or all of the visualization to a scalar number, thus assisting quick comparison, summary, and calculation (for examples of student projects of this sort see McGee, 1995). Second, is the ability to zoom in on a portion of the visualization, so as to focus in on a selected section. For example, a student might want to zoom in on a single continent or the poles. Third, is the ability to look at data over time by averaging multiple data sets of the same quality, extracting point data over time, and creating animations. At a minimum, annual means should be provided for the all the data sets. Fourth, we would add arithmetic operations on the data sets including addition, subtraction, multiplication, and division. These operations could be subjected to some semantic checking (e.g. to ensure that only like units are added or subtracted). The intention is to provide for flexible analysis of the data sets. Providing these arithmetic functions would allow students to calculate the amount of cloud forcing* as detailed by Ramanathan et. al (1989). Fifth, is the ability to spatially correlate data sets. This would provide a means to help determine the relationship that holds between two data sets (e.g., is one data set a linear or exponential function of another). Such patterns can help in understanding the underlying causality. Several means to perform such a correlation are being investigated, in particular, a multi-dimensional histogram or scatter plot could be created where the values in the two data sets provide the x and y coordinate axes and points are plotted from the values at the latitude and longitude positions in the two data sets (e.g., the values at location 42°N, 88°W would compose the x,y coordinates of a point). The correlations are detected by the way the points cluster (e.g., in a linear correlation the points would line up).

6. USING THE GEV WITHIN THE SCIENCE CLASSROOM

Studying the greenhouse effect provides an integrated approach to science, since its understanding relies on atmospheric chemistry (e.g., spectral characteristics of greenhouse gases and their interactions in the environment), physics (e.g., electro-magnetic spectrum and relating temperature and radiation through the black-body model), biology (e.g., role of forests and plankton in carbon cycle), and earth systems science (e.g., consideration of the earth, atmosphere, and oceans as an integrated system). In addition, using models is essential, as is assessing their limitations. A general goal for any greenhouse effect curriculum is helping the student to understand why so many uncertainties persist. The GEV can aid inquiry in these areas by exploring specific processes and use of models.

6.1 *Learning about radiation balance and greenhouse effect*

Using selected visualizations from the GEV a variety of topics can be explored in the classroom. In general, the suggestions are either to compare differing data sets within the same model or to compare the same data set visualizations in different models. The following are example investigations:

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* Visualizations rendered in color can be found on the Collaborative Visualization World Wide Web Server (http://www.covis.nwu.edu).

* Cloud forcing refers to the overall effect of clouds on temperature, that is, do clouds cause a net increase or decrease in surface temperature.

- Compare insolation for January and July to observe the change over seasons. Ground the source of this change in the rotation of the earth around the sun and the earth's tilt off the ecliptic.
- Deduce how insolation would differ when earth is in different stages of the Milankovitch cycle. It might be attractive for this variability to be incorporated into the GEV when calculating surface temperature.
- Examine insolation, albedo, and shortwave reflection to find their relationship. Use this to explain why the poles stay relatively cool during their summer.
- Compare clear and cloudy albedos to see the impact of clouds. In particular, examine how the lack of the intertropical climate zone (ITCZ) affects the tropics.
- Compare the absorbed solar radiation with the surface temperature in order to see the effects of atmospheric heat transports.
- Observe the differing thermal inertia of ocean and land by subtracting January's surface temperature from July's. Explore the interaction between land and ocean by contrasting a El Niño with a La Niña year.
- Contrast the surface temperature between the three models to see the effects of an atmosphere and of clouds.
- Look for a correlation between greenhouse effect amount and percent.
- Explore the effect of increased CO_2 on surface temperature by varying the amount present. Note and explain which areas of the globe are most affected.

6.2 *Learning about Models through the GEV*

The GEV models exemplify several important practices in the use of models by scientists that are of value to students:

- Use of multiple models to understand a single phenomena, where each model is differentiated by order of magnitude effects.
- Importance of feedback loops (including forcing agents) in describing effects of a change.
- Use of balance to describe a complex ecology. For greenhouse effect the essential balance is of energy; for a wetland the essential balance is of water -- in both cases the ecology is analyzed by tracing out a balance.

6.3 *GEV in the classroom*

During the 1994-1995 school year, we will be including the GEV as a new educational resource in a number of high school classrooms in the Chicago area, and formatively improving its interface and educational utility through learner and teacher feedback and re-design. Earth science and environmental science teachers and students will be studied in their use of this visualization package, and how it is complemented by print and video resources, in service of completing their curriculum. We will be particularly concerned to determine what forms of support are needed to guide students' use of their physical intuitions and prior knowledge about heat, temperature, sunlight, reflectivity, feedback, and balance as they bear on the relationships among radiation, atmosphere, clouds, and the electromagnetic spectrum as used in service of understanding the greenhouse effect. Since key conceptual relationships in the models are defined in terms of mathematical formula involving algebraic relationships and new kinds of semantic units (e.g., watts per meter squared), we will identify how the requisite knowledge for understanding these underlying mathematical considerations may be effectively built up through instruction around examples, when students do not have the proficiencies required. While section 6.1 outlines some investigations the GEV will enable, the relative difficulties of such projects for high school students, and modifications of their design required for student success in their inquiries, remain to be determined through this fieldwork and curriculum design with teacher guidance.

7 CONCLUSION

The international focus on greenhouse effect can serve to form a nexus for a course of study in science by providing a single issue that combines fundamental material from diverse scientific areas and is of crucial importance to world wide economic policy. The GEV can help to explore some of this phenomena. In particular, the GEV allows:

- physical processes to be shown, discovered, and analyzed visually
- exploration via a succession of models that isolate order of magnitude effects
- student investigation of state-of-the-art research data sets

The goal is to enable science students to successfully engage in the practices of science, rather than memorizing a simulacrum of its products. We welcome feedback and use of the GEV as it develops from both the scientific and educational community.

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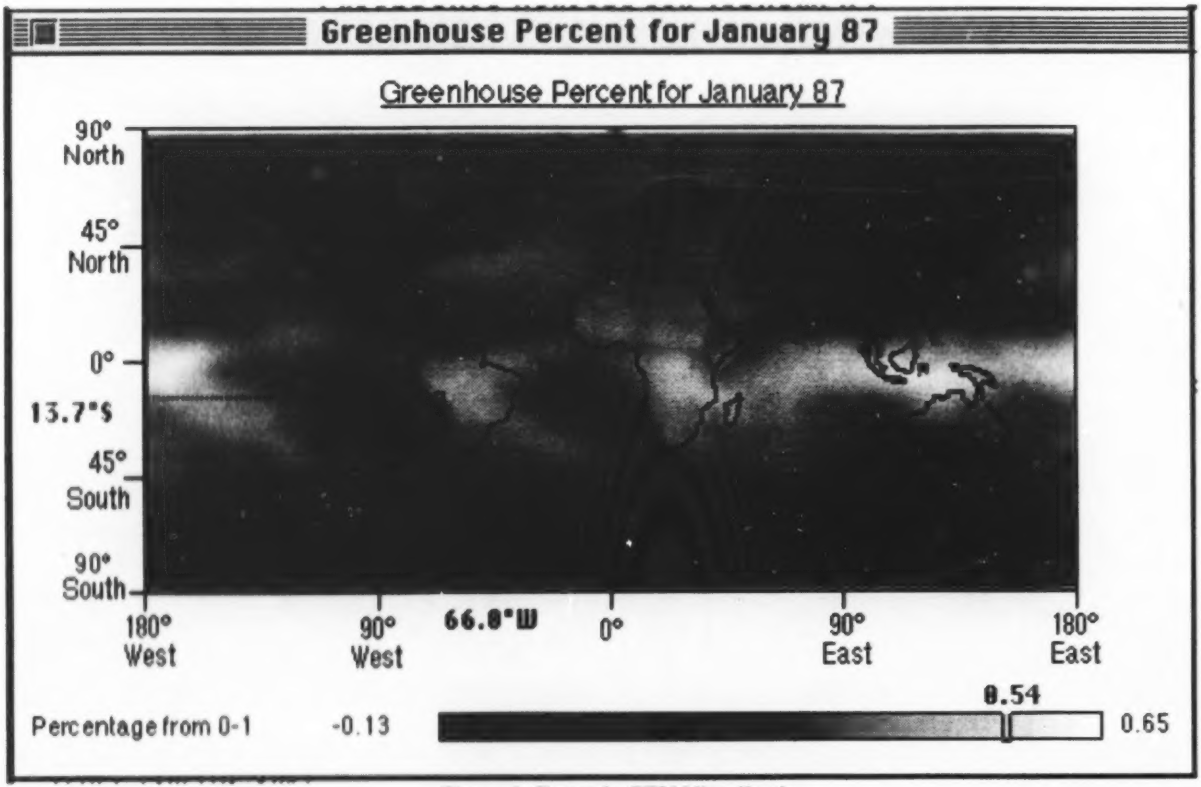

Figure 1: Example GEV Visualization

WHERE IS YOUR DATA?
A LOOK AT STUDENT PROJECTS IN GEOSCIENCE

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1. INTRODUCTION

After eight years of science in elementary school, many students view science as a set of facts to be memorized that have little bearing to their life outside of the classroom (Linn & Songer, 1992). At the high school or college level, students who have successfully completed courses in physics, often cannot solve basic "real-world" Newtonian problems (Halloun & Hestenes, 1987). In an effort to address problems such as these in the textbook-based curricula, state agencies (California State Board of Education, 1993), scientific organizations (Rutherford & Ahlgren, 1990), and the federal government (U.S. Department of Education, 1991) have all called for a revamping of science education through science education standards that emphasize higher-order cognitive abilities.

Unfortunately, teachers are often caught in the middle between science standards, on the one hand and published curricula, on the other hand, which usually lag far behind reform efforts. Teachers are often left with a choice between using a published textbook-based curriculum which does not support the science standards or creating their own alternative curriculum. Because of the isolated nature of teaching, even teachers who are successful in implementing an alternative curriculum find it difficult to share their successful experiences with other teachers (Ruopp et. al., 1992). As a consequence, teachers may often be reinventing solutions that others have developed before them. This makes it very difficult for most teachers to reform their teaching practices.

With the support of the Learning Through Collaborative Visualization (CoVis) Project, six high school earth science and environmental science teachers have undertaken an effort to reinvent their own curricula to incorporate open-ended science projects (Pea, 1993). Some of the teachers are extending their textbook-based curriculum to include science projects, while others have completely abandoned the textbook and are almost entirely pursuing a project-based approach. As is called for in many of the science standards, most of the CoVis teachers feel that project inquiry should be consistent with the nature of scientific inquiry (Rutherford & Ahlgren, 1990). Therefore, most of the CoVis teachers require a project to contain a research question, data analysis that supports an investigation of the question and conclusions based on data analysis.

The goal of this work is to begin to gauge the progress that the CoVis teachers have made toward implementing alternative project-enhanced or project-based curricula and to document their success at reinventing their curricula so that other teachers do not have to start from scratch when they want to reform their own curricula.

2. THE STRUCTURE OF STUDENT PROJECTS

All of the CoVis teachers went through at least two project cycles during the 1993/1994 school year, which is defined as the time from which a project is first assigned until the day the project is due. Student-directed project cycles ranged in length from three to sixteen weeks. The importance that the CoVis teachers placed in project pedagogy can be seen in their allocation of time to classroom activities. Overall, the CoVis teachers allocated 58% of their class time to project related activities (see Table 1). Textbook-based lecture and lab activities account for only 30% of overall CoVis class time. Even those teachers who are extending their textbook-based curriculum, have placed an emphasis on project activity.

In a typical project cycle, students were given an initial period of time to explore a topic through reading reference material, through watching videos, or through class discussion. During this exploratory period students were expected to narrow their focus to a research question and to decide on their project team. The number of team members on a project team ranged from one member to ten members. The average number of team members fell somewhere between two and three members.

After deciding on a research question students typically developed a formal research proposal that was submitted to the teacher. This offered an opportunity for teachers to provide feedback and guide students' project work. Once a proposal was accepted, students conducted their research and shared their results. For most of the projects, students shared their results by submitting a written report to the teacher and by giving an oral presentation to their classmates. For the remaining projects, students shared their results in other formats,

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Classroom Activity	Percent of Total Class Time
Project	58%
Lecture or video	13%
Lab or activity	17%
Test or review	7%

TABLE 1: Proportion of overall CoVis class time devoted to different classroom activities

Data Source	Percent of Data-oriented Projects
Hands On	36%
Community Dataset	35%
Reference Material	36%

TABLE 2: Proportion of student projects that acquired their data from different sources

such as, making a video, a poster, or a computer animation or hypermedia document.

A central concern that the CoVis teachers have shared at teacher meetings is the difficulty that students have in working with data. Research indicates, that students gain very limited experience in school using the tools that scientists use to reason about phenomena (Pea et. al., in press). Therefore, it is no wonder that students in the CoVis classes have had difficulty in using data in their projects. The teachers reported that students had difficulty in finding and selecting the right data for their question, in organizing and manipulating their data, and in conducting systematic (either quantitatively or qualitatively) analyses of their data.

By analyzing the final project reports from the CoVis student projects, it is possible to gain insight into the nature of these difficulties in such a way that other students and teachers can benefit from these experiences. The projects have been categorized according to the source of the data, the format of the data, and the use to which the data was put.

3. STUDENT USE OF PROJECT DATA

Of 298 student-directed projects that were conducted across all twelve of the CoVis classes, 231 final project reports were obtained (78%). The remaining projects either did not have a final report or the reports were unavailable. An analysis of the project reports revealed that 54% (n=125) of the projects did not incorporate any substantive data in their project analysis. These projects were not considered further in this report.

3.1 Sources of data for student projects

Of the remaining 106 projects, Table 2 indicates the percentage of projects that acquired their data from different sources. The numbers do not sum to 100% because several projects used data from more than one source. The Hands On category includes data collected from experiments, observational measurements such as water testing, and the construction of physical models, such as the construction of a wave tank to simulate tsunami waves. The Community Dataset category includes data that was acquired directly from the scientific community, either from one of the CoVis *Visualizers* (see below), from internet ftp sites, from scientists or from scientific organizations. The Reference Material category includes data acquired from reference material such as books, almanacs, newspapers, periodicals, etc.

The CoVis Project provides students with direct access to the scientific community. Each high school has one CoVis classroom with 6 CoVis workstations. The workstations are networked to the Internet and provide a standard suite of Internet tools that allows students to communicate with scientists via email and news and to access datasets available at various ftp sites.

The CoVis Project has produced three visualization environments with student appropriate interfaces to data from the scientific community. The *Climate Visualizer* provides access to visualizations from a National Meteorological Center dataset of temperature, pressure and wind over the northern hemisphere from a 25 year period (see Gordin, Polman, & Pea, in press). The *Weather Visualizer* provides access to the real-time satellite photos, weather maps, and station reports that University of Illinois, Urbana-Champaign generates from the National Weather Service data (see Fishman & D'Amico, 1994). The *Greenhouse Effect Visualizer* provides access to visualizations from the Earth Radiation Budget Experiment dataset, such as albedo, insolation, and outgoing radiation for the purpose of investigating the earth's energy balance. (see Gordin & Pea, 1995, in this volume).

This Community Dataset category is one in which the CoVis Project had a direct influence on the classroom. Without the technology that the CoVis environment provides it would be very difficult for students to gain access to datasets from the scientific community. They would be limited to phone and postal mail interactions. Using the Internet and the *Visualizers*, students can gain easier access to datasets from the scientific community.

3.2 Format of data for student projects

Table 3 indicates the percentage of projects that used different formats. The first number in each cell represents the percentage of projects that received data in that format. The number in parentheses indicates the percentage of projects that used that format for drawing conclusions. Many of the projects transformed the initial data they received. In the Hands On category, students for the most part recorded their data in numerical or qualitative format. In the Community Dataset category, students were as likely to get a

	Graph	Map	Visualization	Numbers	Qualitative	Photograph	Satellite Image
Hands On	3% *(31%)*	0% *(0%)*	0% *(0%)*	77% *(49%)*	28% *(26%)*	3% *(3%)*	0% *(0%)*
Community Dataset	3% *(41%)*	14% *(19%)*	38% *(14%)*	41% *(30%)*	8% *(5%)*	0% *(0%)*	11% *(11%)*
Reference Material	3% *(38%)*	26% *(23%)*	0% *(0%)*	67% *(31%)*	18% *(13%)*	3% *(3%)*	0% *(0%)*
Total	3% *(40%)*	14% *(15%)*	13% *(5%)*	67% *(40%)*	20% *(16%)*	2% *(2%)*	4% *(4%)*

TABLE 3: Proportion of student projects using different data formats as a function of source

visualization from one of the visualizers as they were to receive a table of numbers. Maps and satellite images were also prevalent in these projects. In the Reference Material category, students were most likely to get a table of numbers, but also received maps and qualitative data. Overall, students mostly received their data in numerical format, followed by qualitative descriptions, visualizations and maps.

In many cases, the format that students ultimately used for drawing conclusions involved a *transformation* of the original data format. Such transformations usually involved creating a *graph* from a table of numbers. In the Community Dataset category, students also created *maps* and used the visualizations to create *tables of numbers* from specific points in the visualizations which were sometimes graphed.

Overall, students were as likely to draw conclusions from a table of numbers as they were to draw conclusions from a graph. A significant number of projects in the Community Dataset category (14%) used visualizations to draw conclusions through visual analysis. However, in very few instances did students attempt to build a mathematical model of their data. Results were mostly based on intuitive inspection of a table of numbers, a graph, a map, or a visualization. We consider this an important instructional finding, since we would hope for movement toward model-based inquiry and argumentation.

3.3 Use of data in student projects

Table 4 indicates the percentage of projects that made different uses of the data. In most cases the projects attempted to describe a cause-effect relationship between two or more variables. As was mentioned earlier, most of these cause-effect relationships were not described mathematically. The students mainly developed qualitative and descriptive relationships.

A use that was prevalent in the Community Dataset category and the Reference Material category was finding patterns. In this case, the students took one variable and plotted it either temporally or spatially. There was no attempt made to draw a cause/effect conclusion. The students were interested in the temporal or spatial distribution of a given variable. It is interesting to note that very few Hands On projects attempted to find patterns. It is possible that since the students, in the Hands On category, collected the data themselves and there was a relatively small amount of data, they had a better understanding of where the numbers came from and they could better take advantage of the data to build relationships with other variables. Since the students do not necessarily understand the data that they have received from the scientific community or from reference material, it becomes an important goal just to try to understand what the data is telling them about the given phenomena.

In all but one of the projects in the Make Prediction category, the students based their prediction on a mathematical extrapolation from current data. In the other project, the students gave a weather prediction for the next day based on the previous weeks worth of satellite and temperature data. Even though they made a numerical prediction, it was not clear from the report how they came up with the numbers.

Although most of the projects in the Make Prediction category developed simple mathematical models to create their predictions, none of them tested their model predictions in order to refine the model. Therefore, there were no projects in the Reference Material and Community Dataset categories that tested their own models. Instead, the projects in those categories tested the accuracy of scientist's model predictions. For example, one student tested Iben Browning's earthquake prediction model against actual earthquakes and the phases of the moon. In the Hands On category, several projects attempted to build physical simulation models of physical phenomena. For

	Cause/Effect Relationship	Make Prediction	Test Model	Find Patterns	Compare to Norm	Classification
Hands On	67%	0%	23%	3%	13%	3%
Community Dataset	59%	11%	3%	30%	0%	3%
Reference	64%	10%	5%	13%	0%	3%
Total	69%	8%	11%	16%	5%	3%

TABLE 4: Proportion of types of data use in student projects as a function of data source

example, one group built a wave tank to simulate the formation of a tsunami wave. Unlike the other two categories, the collection of numerical and qualitative data in the Hands On category was in the service of not only testing the accuracy of the model, but also providing information for refining the model in subsequent model runs.

During the course of the school year, the theme of water quality emerged as an important topic to the CoVis students. Most of the projects in the Hands On category that collected data to compare to a norm involved testing water quality. Students either collected water samples from their school drinking fountains or they collected water from local rivers to determine how clean the water was. In some cases, students tried to infer the effect of local conditions such as the location of a water treatment plant on the quality of the North Branch of the Chicago River.

4. CONCLUSION

An analysis of the final reports from the CoVis student projects has provided insight into the nature of students' difficulties in working with data. (1) Only 44% of the projects used data for drawing conclusions. Many of the projects were well designed but the students were not able to find the appropriate datasets to conduct their research. More student-appropriate datasets need to be provided to extend the number of data-oriented projects that students can conduct. (2) None of the projects incorporated mathematical comparisons between variables. Since many of the datasets that the students used were relatively small, it might be possible to provide tools for doing simple correlations and t-tests. (3) Several of the projects developed simple models for the purpose of prediction. However, these students should be encouraged to create and compare alternative models and to test the model predictions for the purpose of refining their models. (4) Environmental science issues are highly motivating for high school students. By having students collect their own data around a highly motivating topic, students may gain a better understanding of the relationship between the data and the phenomena.

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ANALYSIS AND DISPLAY OF SINGLE AND MULTIPLE DOPPLER RADAR DATA USING GEMPAK AND VIS-5D

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1. OVERVIEW OF GEMPAK AND VIS-5D

GEMPAK is a software package originally developed at the Goddard Laboratory of the National Aeronautic and Space Administration (NASA) and now under continued development at the National Meteorological Center (NMC), with additional functionality contributed by Unidata (a program of the University Corporation for Atmospheric Research). GEMPAK is designed to utilize surface weather data (from both fixed and mobile sites), rawinsonde data, gridded numerical data, satellite imagery, and lightning data. GEMPAK is distributed free of charge to universities through Unidata.

Vis-5D is a software package under development at the Space Science and Engineering Center at the University of Wisconsin, Madison. The package permits the visualization of three-dimensional gridded meteorological fields, using isosurfaces, two-dimensional slices, trajectories, and looping. Vis-5D software is available free of charge from the University of Wisconsin.

Together, these two software packages allow the university scientist to undertake comprehensive explorations of gridded data sets. The strength of GEMPAK lies in its flexibility and range of applications: it supports arbitrary user-defined functions and complete control over the plotting and appearance of the graphical information. With this strength comes the cost of relative difficulty in understanding and using the GEMPAK programs. Vis-5D is almost entirely mouse-based and built for speed, and as a result is relatively easy to learn to use. Its weaknesses are its lack of precision and the need to specify user-defined functions ahead of time.

Neither package was designed to analyze and display radar data, but there are obvious advantages to being able to do so. With GEMPAK, one could perform precise, quantitative cross-sections of raw fields, such as reflectivity, and derived fields, such as divergence. Streamline capabilities and time-height cross sections are available as well. With Vis-5D, one could synthesize the ordinarily vast amount of radar data into a three-dimensional image and examine spatial relationships between features and airflow through the system.

This paper reports on the development of software to transform radar data into GEMPAK and Vis-5D formats, and the use of these software packages in radar research and education.

2. TRANSLATION SOFTWARE

Both pieces of translation software assume that the radar data is available in a Cartesian format known as Mudras. This format is commonly used by National Center for Atmospheric Research software packages for performing multiple-Doppler analyses. Existing software, such as Reorder, performs a Cressman analysis to convert

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Universal format radar data, in polar coordinates, onto a regularly-spaced Cartesian grid.

GEMPAK is capable of transforming and plotting in a wide range of projections. To transform the Cartesian radar data onto a georeferenced grid in Gempak format, we have developed the program Georad. Using the known Cartesian grid spacing and the latitude and longitude of a reference grid point (normally the location of a radar), the upper right and lower left locations of the grid are computed and the grid is stored as a Lambert Conformal Conic projection true at the northern and southern latitudes. The vertical coordinate remains height.

The version of Vis-5D presently available to us requires a latitude-longitude grid. In order to avoid interpolation of data and resulting loss of information, the program Convrad specifies a bogus grid location centered along the equator. As a result, the aspect ratio and angles of the Cartesian grid are preserved, but at the expense of any georeferencing information.

Most multiple Doppler radar data exists at only one time, or at a few widely-spaced times. To take advantage of the trajectory capabilities of Vis-5D, Convrad produces multiple copies of the radar grids, evenly-spaced in time. If the velocities stored in the radar files include storm-relative winds, this allows the computation of both instantaneous storm-relative streamlines and steady-state storm-relative trajectories.

3. USES

Examples of the use of GEMPAK and Vis-5D for the analysis and display of radar data will be presented at the conference. We will include a Vis-5D videotape of flow visualization for an observed mesoscale convective system. These capabilities are used for classroom instruction, for hands-on manipulation of data in the computer laboratory, and for research into the structure and dynamics of mesoscale convective systems.

The georeferencing capabilities of GEMPAK are especially useful when dealing with mobile radar platforms. Observations from two different times can easily be overlaid and compared. An additional grid diagnostic function, called MAX, has been added to GEMPAK for use with airborne radar reflectivity data. The MAX function accepts two colocated grids as input and selects the largest value at each grid point as output.

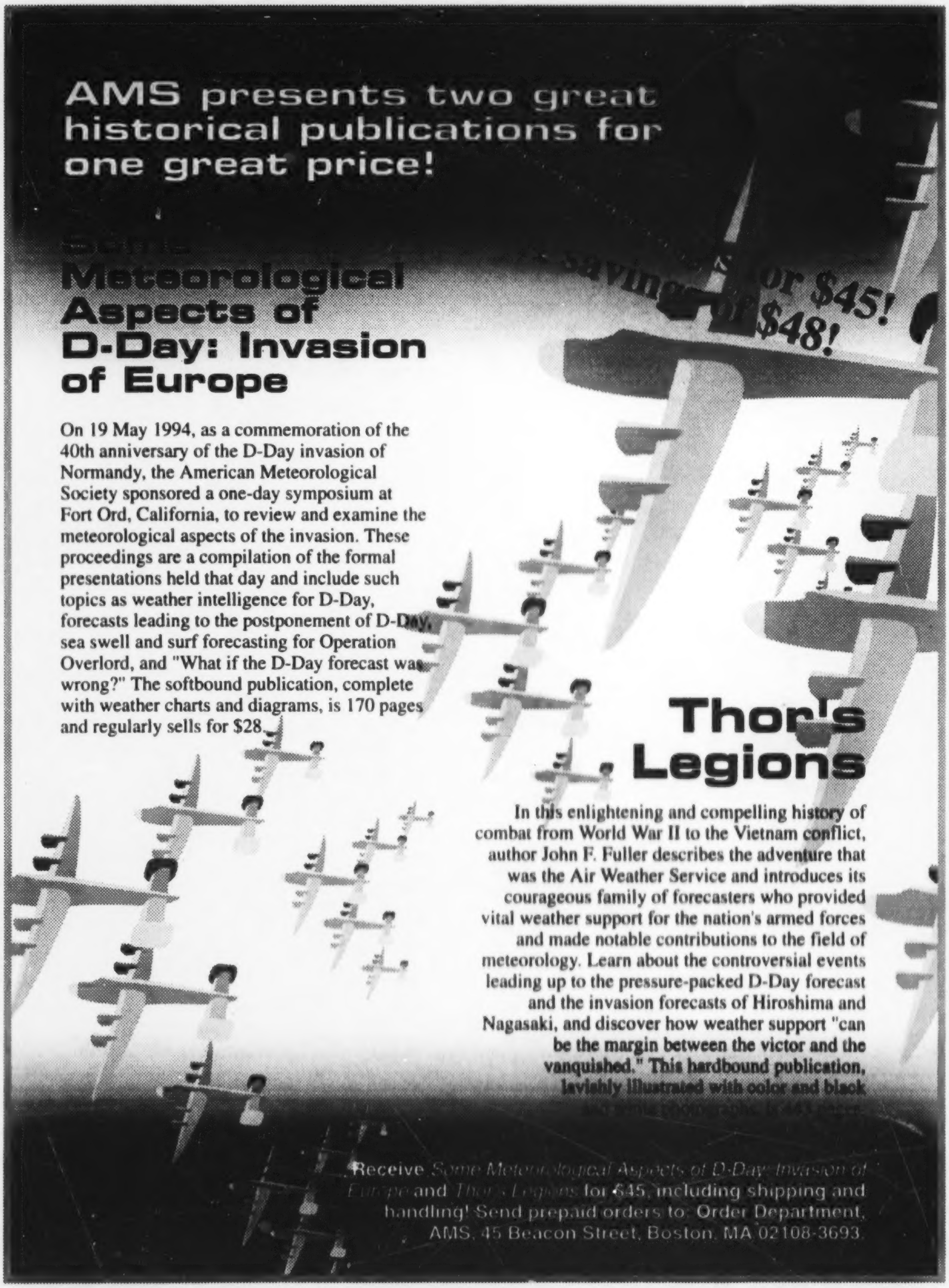
In our first classroom application of this capability, the METR 452 class (Dynamics of Weather Processes) used Vis-5D during their study of squall lines. The class consisted of thirty students, who utilized our computer laboratory, the Laboratory for Meteorological Data Analysis, which includes fourteen SGI workstations. The students, after hearing a discussion of squall line structure, were walked through a visualization of the 28 May 1985 PRE-STORM squall line system. They were shown, for example, how the location of the rear-inflow jet affects the intensity of the convection. They were then given the opportunity to examine other fields and isosurfaces and to rotate the view to obtain different perspectives of the field. This gave the students a fully three-dimensional mental model of a real-life squall line, including the along-line variability, that would have been otherwise unattainable.

4. AVAILABILITY

Georad and Convrad are available free of charge from the Department of Meteorology at Texas A&M University. Please email us if you would like to obtain the software.

5. ACKNOWLEDGMENTS

The Laboratory for Meteorological Data Analysis was funded through the Instrumentation and Laboratory Improvement program of the National Science Foundation, under grant DUE-9352601, and by Texas A&M University.



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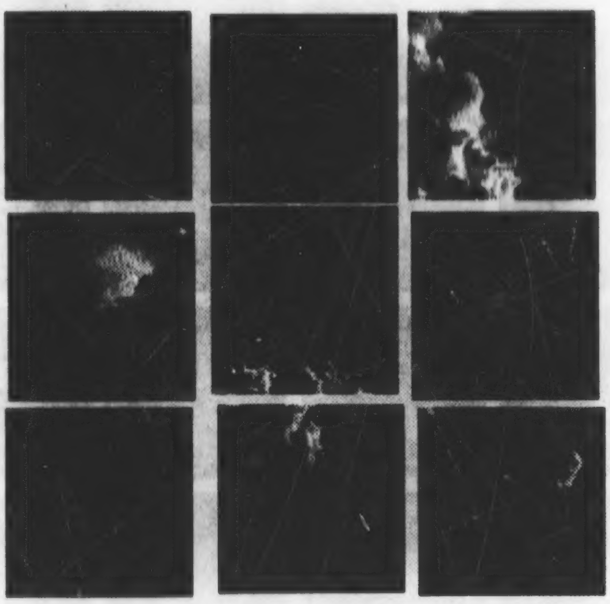

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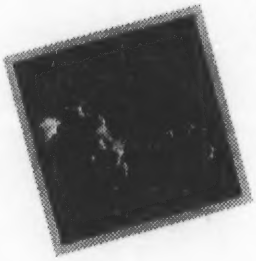

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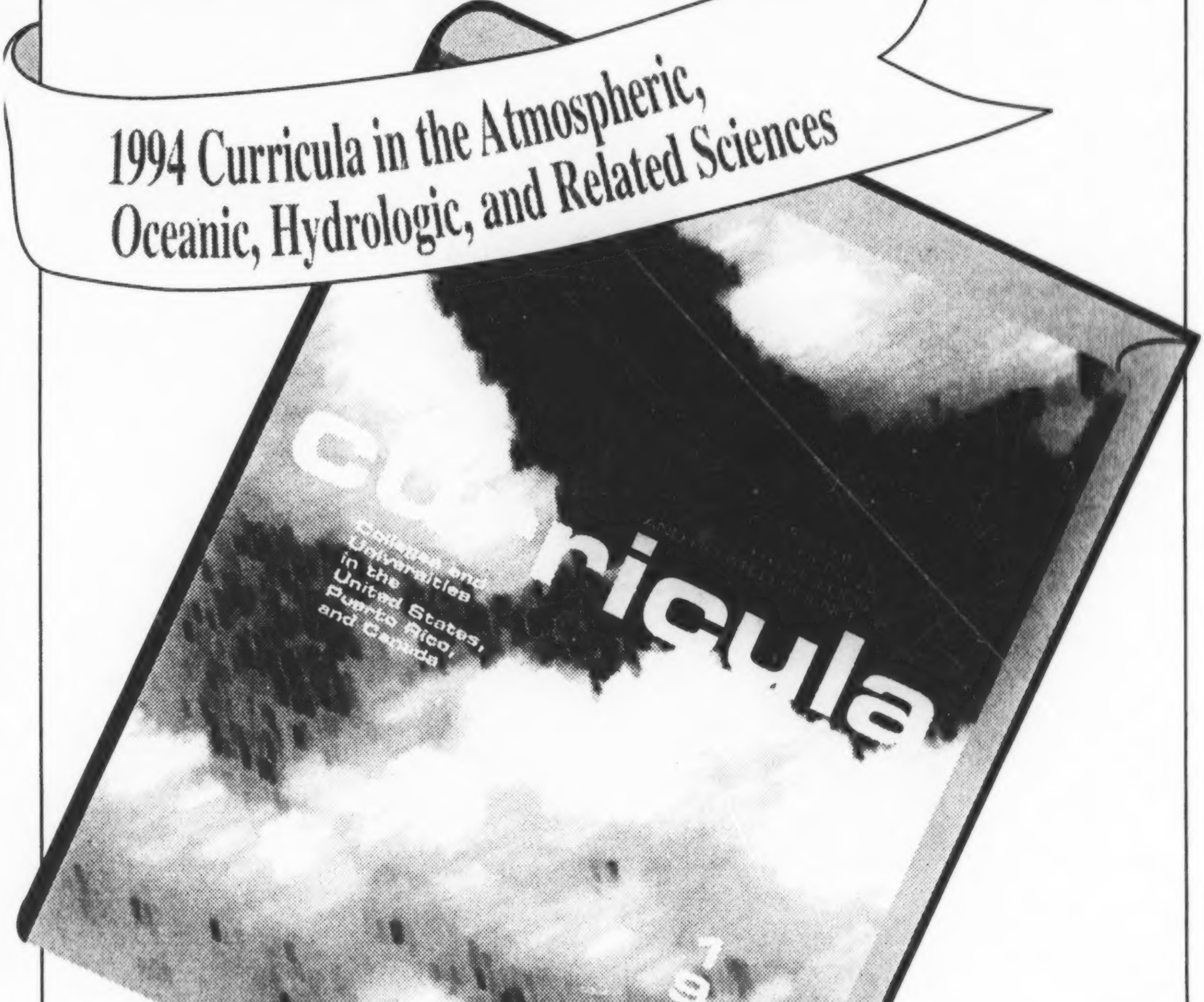
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